BRAINPOWER CONGRESS 2023

ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

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"ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
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สารบัญ

ด้านการพัฒนากำลังคนทักษะสูง (Reskill/Upskill)	**ห้องที่ 1**
ชื่อโครงการ	หน้า

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Space Technology, Quantum Technology, High Energy Physics, Plasma)	ห้องที่ 2
ชื่อโครงการ	หน้า

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Space Technology, Quantum Technology, High Energy Physics, Plasma)	**ห้องที่ 2**
ชื่อโครงการ	หน้า

ด้านอุตสาหกรรมแห่งอนาคต (Future Industry - GHG Net Zero)	**ห้องที่ 3**
ชื่อโครงการ	หน้า

ด้าน Global League and Research Institutions Re-Inventing	ห้องที่ 4
ชื่อโครงการ	หน้า

ด้าน Global League and Research Institutions Re-Inventing	ห้องที่ 4
ชื่อโครงการ	หน้า

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Omics Technology, Immunology, Tissue Engineering)	**ห้องที่ 5**
ชื่อโครงการ	หน้า

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Omics Technology, Immunology, Tissue Engineering)	**ห้องที่ 5**
ชื่อโครงการ	หน้า

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Aquaculture, Biotechnology)	ห้องที่ 6
ชื่อโครงการ	หน้า

ด้านการพัฒนากำลังคนทักษะสูงและงานวิจัยขั้น แนวหน้า (Artificial Intelligence, Coding)	**ห้องที่ 7**

ด้าน Global Partnerships (Materials, Battery, Energy)	ห้องที่ 8
ชื่อโครงการ	หน้า

ด้านมนุษย์ศาสตร์ สังคมศาสตร์และศิลปกรรมศาสตร์ (Covid 19 & Soft Power - Creative Economy)	**ห้องที่ 10**

ด้านการพัฒนากำลังคนทักษะสูง (Industrial/Frontier Postdoc) ด้านเกษตรอาหาร การแพทย์	**ห้องที่ 1**
ชื่อโครงการ	หน้า

ด้านการพัฒนากำลังคนทักษะสูง (Industrial/ Frontier Postdoc) ด้านเกษตรอาหาร การแพทย์	**ห้องที่ 1**
ชื่อโครงการ	หน้า

ด้าน Research Infrastructure	**ห้องที่ 2**
ชื่อโครงการ	หน้า
ระบบศึกษาการเปลี่ยนแปลงมวลสารของวัสดุ สมบัติเชิงเคมี และความร้อน และการวิเคราะห์ผลิตภัณฑ์แก๊สที่เกิดขึ้นจากการให้ความร้อนในสภาวะเสมือนจริงแบบครบวงจรสำหรับเทคโนโลยีการลดการปลดปล่อยคาร์บอน ดร.บุญรัตน์ รุ่งทวีวรนิตย์ *สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ (สวทช.)*	**259**

ด้านการพัฒนางานวิจัยอุตสาหกรรมแห่งอนาคต (Future Industry - GHG Net Zero)	**ห้องที่ 3**
ชื่อโครงการ	หน้า

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Medical AI, Immunology, Biomarker, Tissue Engineering)	**ห้องที่ 5**

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Energy, Physics, Mathematics)	**ห้องที่ 7**
ชื่อโครงการ	หน้า

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Energy, Physics, Mathematics)	ห้องที่ 7
ชื่อโครงการ	หน้า

ด้าน Global Partnerships (Medicinal & Virus)	**ห้องที่ 8**
ชื่อโครงการ	หน้า

การพัฒนากำลังคนทักษะสูง (Industrial/Frontier Postdoc) ด้านเกษตรอาหารและการแพทย์	**ห้องที่ 1**

การพัฒนากำลังคนทักษะสูง (Industrial/Frontier Postdoc) ด้านเกษตรอาหารและการแพทย์	**ห้องที่ 1**
ชื่อโครงการ	หน้า
การพัฒนาระบบควบคุมการสะสมน้ำมันในยีสต์แบบใหม่ในระดับการถอดรหัสและการวิเคราะห์ปฏิสัมพันธ์ของโปรตีนในวิถีที่เกี่ยวข้องด้วยเทคโนโลยีโอมิกส์ ผศ. ดร.พิชามญชุ์ เกียรติวุฒินนท์ *มหาวิทยาลัยเกษตรศาสตร์*	**457**

การพัฒนากำลังคนทักษะสูง (Industrial/Frontier Postdoc) พลังงานหมุนเวียน วัสดุขั้นสูง ดิจิทัลและปัญญาประดิษฐ์	ห้องที่ 2
ชื่อโครงการ	หน้า

การพัฒนากำลังคนทักษะสูง (Industrial/Frontier Postdoc) พลังงานหมุนเวียน วัสดุขั้นสูง ดิจิทัลและปัญญาประดิษฐ์	ห้องที่ 2
ชื่อโครงการ	หน้า

การพัฒนางานวิจัยขั้นแนวหน้า (Engineering, Chemistry)	**ห้องที่ 3**
ชื่อโครงการ	หน้า

Global Partnerships (Chemistry, Biology, Environmental)	**ห้องที่ 4**
ชื่อโครงการ	หน้า
พัฒนาความเข้มแข็งแบบแผนการจัดการขยะเพื่อตอบสนองผลจากภัยพิบัติและจากการเปลี่ยนแปลงสภาพภูมิอากาศ รศ. ดร.สิรินทรเทพ เต้าประยูร *มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี*	**525**
กรอบแนวคิด การดำเนินการ และมาตรการ สำหรับเศรษฐกิจหมุนเวียน จากระดับจุลภาคถึงระดับมหภาค ศ. ดร.ชนาธิป ผาริโน *คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย*	**528**

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนากำลังคนทักษะสูง (Reskill/Upskill)

The Rajamangala University of Technology's Talent Resource Management Platform for Reforming the National Manpower Production System (TRM PLUS)

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[a]Rajamongala University of Technology Thanyaburi, [b]Rajamongala University of Technology Suvarnabhumi, [c]Rajamongala University of Technology Lanna, [d]Rajamongala University of Technology Isan, and [e]Rajamongala University of Technology Srivijaya.

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Project duration: 1 year, from 1 August 2022 to 31 July 2023

Current progress: 100%

Abstract:

"TRM PLUS," has been supported by the Program Management Unit for Human Resources and Institutional Development, Research and Innovation (PMU-B). The project aims to develop an efficient TRM platform implemented in 2021 to enhance national productivity by advancing the talent mobility system. The TRM platform has 3 main dimensions: scouting, grooming, and utilization. Talents have been scouted into 6 levels based on their experience with enterprises, ranging from less experienced to high-potential talents. Grooming programs are designed based on talent levels for matching with enterprises through 3 types of projects: basic, impact, and high-impact. Approximately 11% of RMUT talents ready for mobilization are counted on the RMUT data pool. In 2023, the TRM platform produced 145 products, including 3 innovations, 37 machines, 51 production-line technologies, 21 food products, and 31 other goods. All projects generate around 6% of income, reduce 11% of total investment and maintenance costs and gain THB 12.15 million in co-funding into the platform.

Rationales/Problem statements:

The Middle-Income Trap has obstructed Thailand for more than 45 years. To step over the MID, Thailand needs to drive national developments with science, technology and innovation by increasing total expenditure in R&D and mobilizing high-potential scientists, researchers and innovators in real sectors. The Ministry of Higher Education, Science, Research and Innovation responded to these expectations through the "Talent Mobility" project. The TM project aims to mobilize universities' talents to work in enterprises to transfer knowledge and skills in science and technology created or developed in universities to the private sector.

RMUT has been one of the TM networks since 2014. However, in 2020, when RMUT tried to develop its ecosystem to match working with the private sector, it found in the data pool that only 220 RMUT talents were cooperating with enterprises. Therefore, under the one RMUT direction under the ONE RMUT strategies and policies, RMUT studied and piloted a model to meet the University-Enterprise Linkage or UEL, then developed and promoted the TRM platform in 2021.

Objectives:

TRM PLUS has 3 essential goals:

1) To increase the amount number of RMUT talents who have experience in cooperative working with potential enterprises by up to 10%,
2) To cultivate productivity and economic competitiveness in networking enterprises by mobilizing 200 RMUT talents and 100 vocational talents to work with enterprises,
3) To advance Thai enterprises to meet international competitiveness by mobilizing high-potential talents with international experts.

Progress/Findings/Results:

Between 2022 and 2023, the TRM PLUS program trained 524 RMUT and 132 vocational talents. Out of these, 227 newly trained RMUT and 107 vocational talents were employed under the supervision of 111 mentors to work with different enterprises. The platform successfully produced 145 products, which included 3 innovations, 37 machines, 51 production-line technologies, 21 food products, and 31 other goods. These products were developed in different groups such as technology development, IT and big data management, health and wellness, food production, smart agriculture, and BCG products. The TRM PLUS program mobilized a total of 445 talents and 11 international experts to work with enterprises, successfully achieving the project's objectives to increase RMUT talents by up to 11% in the RMUT data pool.

Conclusion:

1) To motivate talent mobility from university to the real sector, grooming methods need to be designed to match the talents' experience and upgrade their skills to match the needs of users and enterprises.
2) The mentor shadow is an efficient method to transfer experience and industry behavior to new talents and create talents' confidence to work with enterprises.
3) Recognition is the key succession to create an achievement in cooperation between universities and enterprises. The recognition comes from any concerns of researchers to make the cooperation meet the enterprise's requirements both the requirement of time and production.

Current Output:

TRM PLUS has successfully generated 6% of income and reduced 11% of total investment across 135 enterprises located nationwide in 47 provinces through its 145 projects. The platform has been instrumental in creating recognition in these enterprises, resulting in gaining THB 4.74 million in co-funding into the platform and a top-up of THB 11.45 million directly to the projects.

Challenges/Problems and Possible solutions:

In order to ensure the long-term sustainability of the platform, it is essential to continuously enhance its capabilities to attract and mobilize highly skilled talents that meet the needs of the private sector. To achieve this, the platform requires a well-structured committee responsible for managing and operating it, as well as a funding method that encourages co-funding from both private and public organizations.

Future plan:

The TRM operations team plans to upgrade the platform for international cooperation, welcome more international experts to collaborate with Thai talents in advanced technology transfer, and create innovation-driven enterprises for international competition.

Talent Resource System Development and Capacity Building for Driving Talent Mobility Ecosystem in Rajabhat University

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Project Duration: 1 year 4 months, from 1 August 2022 to 30 November 2023
Current progress: 90%

Abstract:

Thailand's ambition to become a leading innovation nation requires a strategic approach to human capital development, knowledge institution advancement, and science, research, and innovation ecosystem enhancement.

Universities play a critical role in cultivating a research and development workforce, promoting innovation, and establishing private sector partnerships. Rajabhat Universities, in particular, focus on integrating knowledge into innovation, driving development within community enterprises, businesses, and industries. Their unique value proposition lies in leveraging local identity, cultural heritage, community tourism, and promoting regional industries to unlock distinct economic value.

Therefore, developing the potential of Rajabhat University personnel and establishing management mechanisms to support the creation of an innovation-driven science, research, and innovation ecosystem are crucial actions. This study aims to establish a resource management system for collaborative development with the private sector, enhancing the potential of Rajabhat University personnel and fostering an innovative environment that facilitates research talent mobility.

Rationales/Problem Statements:

To achieve competitiveness and sustainable development, industrial and community enterprises establishments in the region need to grow rapidly. They must enhance business value by leveraging innovation and the region's unique identity. This demands a skilled workforce capable of generating economic and societal value, in which universities play a critical role in developing human capital and utilizing knowledge and innovation to boost the industrial competitiveness. This aligns with Rajabhat University's goal, which aim to produce innovative outcomes based on the region's social resources and societal capital.

However, university regulations hinder collaborative research projects with industries, and insufficient budget continuity impedes the development of a skilled workforce and the establishment of adequate support and operational models. To address these challenges, this project seeks to enhance researchers' knowledge and understanding of collaborative work with the private sector, aligning research with industry needs, generating research value, and creating intellectual property value for the university. This initiative is crucial for promoting collaborative research and creating value for Rajabhat University.

Objectives:

1. To examine and provide recommendations on Rajabhat Universities' regulations or management directives that support the innovation development in collaboration with the private sector.
2. To promote the operation of the innovation network by establishing databases and processing systems that support collaborative innovation with the private sector in Rajabhat Universities in the Northern and Northeastern regions.
3. To enhance the capabilities of personnel in Rajabhat Universities in the Northern and Northeastern regions to utilize university resources for developing innovations for local businesses.
4. To provide support for the implementation of innovation projects in collaboration with entrepreneurs.

Progress/Findings/Results:

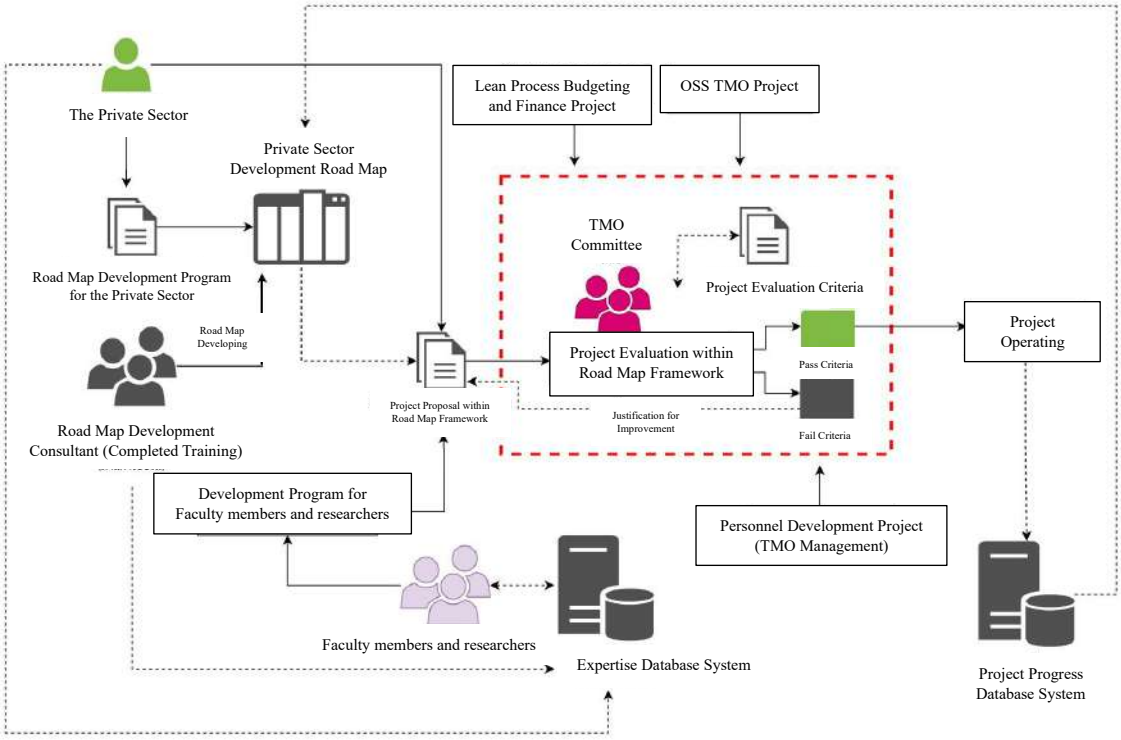
Thailand is currently experiencing a surge in innovation and research, harnessing the power of science and technology to develop business applications that enhance competitiveness and effectively address human needs. This has had a positive impact on various aspects, particularly in research and innovation projects. Notably, 19 successful collaborative projects involving researchers, administrators and coordinators from Rajabhat Universities in the Northern and Northeastern regions have focused on collaborative initiatives with communities and industries. In terms of personnel development, 172 individuals from Rajabhat University's Northern and Northeastern regions have undergone capacity development, including 49 administrators, 83 lecturers/researchers, and 40 coordinators. These projects have explored strategies for elevating management units to facilitate collaboration with the private sector and proposed improvements to regulations or management rules to support research and innovation at the university level.

A study of regulations related to innovation development and collaborative projects with the private sector further recommended the establishment of an organizational unit to manage collaborative work with the private sector. This unit would aim to facilitate collaboration with larger industries, create agencies responsible for supporting operational models more efficiently, and promote regulations and management practices that favor collaboration with the private sector. These efforts would encompass the management of general operations and personnel, fostering a clear understanding of collaboration with the private sector, and developing clear indicators.

Regarding the STDB system, a substantial discrepancy exists between the expected (estimated) data and the actual data, ranging from 11.6% to 27.3%. All universities in the Rajabhat group should strive to increase the amount of data in the STDB system to match or closely align with the actual number. This would benefit system users in retrieving information about experts and research, enhance the basic structure for organizations or businesses seeking services, and increase opportunities for collaboration between educational institutions and the private sector.

Conclusion:
A total of 172 individuals from Rajabhat Universities in the Northern and Northeastern regions have successfully completed capacity development training. Subsequently, 19 Pre-Talent Mobility projects have received support for collaborative innovation with businesses. These projects align with the program's objectives and can be categorized according to the size of the businesses involved: community enterprises (63%), small-sized businesses (32%), and medium-sized businesses (5%). When classified by S-CURVE, representing 10 future industries, the distribution of projects is as follows: Agriculture and Biotechnology industry (37%), Food Processing industry (42%), Robotics industry (5%), Digital industry (5%), and other industries (11%). This distribution aligns with the hypothesis that Rajabhat Universities are most actively engaged in collaborative projects with the private sector in community enterprises, primarily within the Agriculture and Biotechnology industry.

Current Output:
Upgrading System: Talent Mobility Office



Challenges/Problems and Possible Solutions:
Within Rajabhat University, there exists a lack of clarity regarding project management practices. Faculty members and researchers often find themselves with limited opportunities for participation in collaborative projects with the private sector, leading to feelings of disengagement among some participants. Additionally, the current number of coordinators is insufficient to provide adequate support for Pre-Talent projects, and there is no dedicated unit tasked with addressing challenges or issues arising from the private sector.

Future Plan:
Drawing upon the insights gained from the analysis of the skills and competencies of coordinators who have participated in capacity development initiatives, a tailored curriculum to develop critical skills can be developed. This curriculum would be designed to further enhance the skills of coordinators, facilitate the establishment of a Clearing

House unit, and promote flexibility in collaborative endeavors involving faculty members, researchers, and the private sector.

Advanced Human Resource Development in Multiomics and Bioinformatics of Medical, Agricultural and Food Sciences

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Project duration: 1 year, from 24 April 2023 to 23 April 2024
Current progress: 60%

Abstract:

Advanced human resource development in multidisciplinary and bioinformatics areas of medical, agricultural and food sciences consist of three sub-projects: Genomics and Precision Medicine courses; Bioinformatics courses for synthetic biology work in the agriculture and food industry The multiomics curriculum in Foodomics is 60% complete throughout the project. All sub-projects have designed and implemented a signage curriculum. Recruiting students and selecting students After that we create a working network plan implementation. In sub-project 2, a synthetic biology non-degree program for industry has been established which includes new/upskill/reskill modules. A total of 15 students received full scholarships and credits were credited to the bank credit system. Next plan, we will organize training courses for new skills/upgrading skills at the non-degree level, sub-projects 1 and 3. The training courses will start in December. and January respectively

Rationales/Problem statements:

Advanced human resource development in the fields of multi-omics and bioinformatics in medical, agricultural, and food sciences consists of three sub-projects: the Genomics and Precision Medicine course, the Bioinformatics course for synthetic biology work in the agriculture and food industry, and the Multi-omics course in Fudomics. Thailand still lacks researchers with advanced expertise in these 3 areas, which are important sciences that must be used in conjunction with modern medicine. Because it will help increase the efficiency of treatment and be more specific to each individual. Therefore, researchers must be developed to enter this advanced medical field. To have Thai researchers with advanced expertise in the future will also be an important force in the development of knowledge. To be used in further developing commercial products to meet the needs of the industrial sector in sustainability.

Objectives:

The objectives are (1) To provide personnel with basic knowledge and skills in the field of medical science. medical bioinformatics and application of advanced technology to enable students to apply skills in the industry in the field of genomics research for precision medicine, (2) Emphasis on research practice in biological data science and bioinformatics. Doing a project in synthetic biology From questions from the government, private sector, and networks through

the Thailand Synthetic Biology Consortium, and (3) Emphasizing the development of knowledge and skills of personnel in the use of high-throughput technology with emphasis on multi-omics science.

Progress/Findings/Results:

1. Genomics and Precision Medicine course

Designed and created public relations signs for the Genomics and Precision Medicine course, recruited students, and select students which will begin studying online this December (figure 1).

Figure 1. Billboards to promote the Genomics and Precision Medicine course.

2. Bioinformatics course for synthetic biology work in the agricultural and food industries

Designed and created public relations signs for the Bioinformatics course for synthetic biology work in the agricultural and food industries, recruited students, and select students, which has already begun in September - October 2023, as shown in the figure 2 -5.

Figure 2. Public relations signs for the Bioinformatics course for synthetic biology work in the agricultural and food industries.

Figure 3. Soft launch ceremony of non-degree program SynBio for industry on September 15, 2023, KU SynBio 1st generation in Thailand.

Figure 4. Activity to observe work at Biome Company Ltd. and receive industrial research questions to develop further.

Figure 5. Seminar activities by experts in synthetic biology

Receive free scholarships for the entire course (15 scholarships) sponsored by the Human Resource Development Grant Administration and Management Unit. and funding for the development of higher education institutions Research and Innovation, and synthetic biology network Faculty of Science Faculty of Agro-Industry international college and the College of Integrative Sciences Kasetsart University together with the Phenome Center Khon Kaen University, Faculty of Medical Technology Khon Kaen University, Siriraj Long-read Lab, Medical Bioinformatics Unit Faculty of Medicine Siriraj Hospital Mahidol University including the Thailand Synthetic Biology Consortium

3. Multi-Omics Short Course in Foodomics

- Brainstorming meeting with stakeholders Gain a stake in production and hire high-performing researchers in Multi-omics and CRISPR-CAS techniques
- Create and develop short courses Multi-omics: Fudomics and CRISPR-CAS techniques.
- Publicize the training and open for registration.

3.1 Multi-Omics Short Course in Foodomics study by expert Asst. Prof. Dr. Jutharop Phetchaburanin and Asst. Prof. Dr. Thidathip Wongsurawat and others)

- The Multi-Omics Short Course working group held a training planning meeting.
- We have opened applications for interested researchers. up-/re-skills in Multi-Omics from all over the country until October 31, 2023. There are currently 401 applicants (information as of October 15, 2023). However, this training can accept only 55 participants, as shown in the figure 6.

Figure 6. Billboards to promote the Multi-Omics Short Course in Foodomics and 401 applicants in application form.

- Applicant selection:

1. The working group created AI to select applications with an emphasis on having an equal number of applicants from various institutions.
2. There are various age groups, Education level, The ratio of male:female is equal, and the working group will also consider applicants' essays.
3. Training will be conducted from 18 January – 2 February 2024.

Conclusion:

All sub-projects have successfully formulated and executed a curriculum with appropriate progression. The process involved student recruitment, selection procedures, and the subsequent establishment of a functional network plan for implementation. Notably, sub-project 2 has established a synthetic biology non-degree program for the industry, incorporating both new and upskilling/reskilling modules. achievement is the provision of full scholarships to 15 students, with credits systematically integrated into the banking credit system. 2 sub-projects will be done soon.

Current Output:
- Receive free scholarships for the entire course (15/80 scholarships)

Challenges/Problems and Possible solutions:
- There's no problem.

Future plan:

1. Future plan of Genomics and Precision Medicine course
-Carry out training courses both domestically and abroad.
-Summary and evaluation

2. Future plan of Bioinformatics course for synthetic biology work in the agricultural and food industries
-Create a working network plan operations and evaluation of the curriculum
-Create a certificate course for Non-degree Synthetic Biology for Industry.
-Carry out training courses reskill/upskill modules in Non-degree synthetic biology for industry
-Organize training courses and brainstorming sessions with industry and foreign experts' new skill module
-Analyze activity data according to expert recommendations.

3. Future plan of Multi-Omics Short Course in Foodomics
-Organize short-term training courses in multi-omics in Fudomics and CRISPR-CAS techniques.

Researcher Capability Boost up for Post-doctoral Researchers in Genomics and Bioinformatics for Health Discovery Research

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a. Chiang Mai U; b. Songklanagrind U; c. Khon Kaen U; d. Kasetsart U; e. National Science and Technology Agency; f. Mahidol U; g. Burapa U.; h. King mognkut U.

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Project duration: 1 year

Current progress: 50%

Abstract:

This project selected 10 biology-based researchers who have some experiences as bioinformatics users. This program spent two years including one course work (reskill and upskill) and thesis-based practice in the first and second year, respectively. Reskill was set by the purpose of adding required capability which include Linux programing, R-programing, python, and bio-statistic for 150 hours. All researchers will spend at least 15 hr/weeks for upskill in data processing with pre-existing projects. Advanced knowledge including cancer genetic epidemiology and genetic epidemiology for non-communicable disease will be transferred (140 hours) from IARC, WHO and Queen's Marry University respectively. All participants will get final examination by experience bioinformatics for capabilities testing. Finally, they will create their own works based on bioinformatics skill in the second year. The learning package will be evaluated and modified for using in graduated program development for participated universities.

Rationales/Problem:

Genomics is a fast-developing research field. The genomics data from human, animal and plants have been created and available in Thailand. Those become important resources of new services or products in health and food sector. Bioinformaticians is the important key person who translates data to those. There are a few bioinformaticians in Thailand which are not sufficient to support the translating genomic data. To create the new bioinformatics and good ecosystem for supporting working process are difficult. On the other hand, good quality of data will be unable to generate without bioinformatic viewpoint. Thailand is facing this vicious cycle and more seriously since the genomic Thailand project was started. The impact of problems have been obviously shown in most of leading universities. There is no good quality of data available to study, no available bioinformaticians to analyze, no sufficient infrastructure to operate, and importantly no standard skill capability to setup new curriculum.

Objectives

1. To increase capability of post-doc researcher from biology field to bioinformaticians.
2. To translate learning-teaching experience for graduated curriculum set up in universities.

Progress/Findings/Results:

1. Ten participants were recruited from 5 universities including 4 from Chaing Mai University, 3 from Songklanakarin University, 1 from Ramathipbodi Hospital of Mahidol University, 1 from Kasetsart University and 1 form Khon Kean University.
2. All participated university agree to co-pay for 80% of post-doc researcher salary.
3. All participated university are agreed to set up workstations, and pre-existing genomic projects for researchers in upskilling program.

4. Linux programing was already finish and participants can reach the acceptable capabilities in using Linux.
5. R-programing and python has been learning and about 50% of overall course.
6. All participants run bioinformatics activities as following project in upskilling programs.

6.1 Whole exome sequencing reveals mutation profiling of Osteosarcoma patients with chemotherapy resistant.
6.2 Somatic mutations landscape and post-operative survival outcome in pediatric patients with neuroblastoma
6.3 Comparative genomic and plastomic of duckweed for future food
6.4 The landscape of somatic and germline alterations in high-risk neuroblastoma
6.5 Neoantigen identification from whole exome sequencing and RNA sequencing and/or proteomics in osteosarcoma cohort
6.6 Integrating liquid biopsy analysis for advanced non-invasive cancer diagnosis and management
6.7 A study on the effectiveness of probiotics on improving the microbiome profile in high fructose-fed rats and Effects of Lactobacillus paracasei TISTR 2593, a probiotic supplement, on microbiome in fatty liver patients.
6.8 Analysis of beta-glucan oligosaccharides induced changing of gut microbiota using bioinformatics tools and Probiotic.
6.9 Rapid identification of carbapemase resistance Acinetobacter baumannii from sputum using Nanopore sequencing and bioinformatic analysis.
6.10 Proteogenomic discovery of tumor specific antigens in osteosarcoma patient with poor response to neoadjuvant chemotherapy.

Conclusion:

1. Project is running following schedule.

Current Output:

1. Recruitment of post-doc researchers for participation in training.
2. Running reskill and upskill program.

Challenges/Problems and Possible solutions:

1. Qualified bioinformatic proposal from 10 participants are still challenge.
2. Sufficient and good quality training data set
3. Standard skill for National capabilities

Future plan:

1. The second year for training program
2. Collaboration with Hub of talent in bioinformatics

Bioinformatics Talent Pool and Effective Stakeholder Engagement

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 85%

Abstract:

Rationales/Problem statements:

PMU-B has expressed a genuine interest in supporting the development of bioinformatics talents in Thailand. In our grant proposal, we had posed 12 research questions, and the expert committee has approved my request to address these questions. Then, 10 researchers from 10 institutes agreed to make this happen as well as all members in Division of Medical Bioinformatics, Thailand.

Objectives: There are 4 objectives, (1) to create a platform for exchanging opinions to understand needs, problems, obstacles, and to establish connections among bioinformatics professionals and relevant stakeholders across Thailand. (2) to promote awareness in the research and service community about the importance of bioinformatics. (3) to provide opportunities for bioinformaticians to access or utilize resources in the country (4) to collect data from meetings to identify ways to promote and support the development of bioinformatics personnel in Thailand, understanding the overall picture and labor market needs.

Progress/Findings/Results: All 12 questions have been addressed, including, (1) the current curricula meet the labor market demands. We now know which universities emphasize the medical, agricultural, or food sectors. (2) We learnt there are the opportunities for bioinformaticians outside Bangkok. (3) Basic infrastructure are found at ThaiSC, National Biobank of Thailand (NBT). AWS genomics might be joined in the future. (4) **The perspectives of bioinformaticians in Thailand show Diverse views; many value Thailand's potential, culture and family reason. However, most of top bioinformatician**
What skills are employers primarily looking for when hiring bioinformaticians? What are the reasons for hiring?
What are the job hiring trends for the future?
What is the importance of research in -omics at various levels?
What tools are required to analyze Genomics Thailand data and for what questions?
What current courses are available for skill development? When are they held, for how long, and what are the outcomes upon completion?
What are some examples of research conducted by bioinformaticians in Thailand?
How will future conferences be structured?
Should a collaboration of bioinformatics personnel, including those involved in medical, agricultural, and food sectors from all over the country, both public and private sectors, take place in the year 2023

We promised of bringing together a minimum of 150 participants for this initiative. With the invaluable support of numerous stakeholders (Amazon Web Services (AWS), Illumina, PacBio, DKSH, Getz Healthcare, Biogenomed, BioDesign CO., LTD., NVIDIA, CARIVA (Thailand), SM Chemical, Bioentist, Geneplus, our efforts have gone beyond our initial expectations, resulting in an impressive gathering of 450 participants. Among these attendees are bioinformaticians, researchers, influential policymakers, and experts in genomics from Thailand.

Private companies including #CPgroup, SynBIO, Genfosis N-Health, #Cariva, #Betagro, and many others, has been instrumental in making this endeavor a resounding success. I am

genuinely thankful for their engagement to advancing bioinformatics in Thailand.

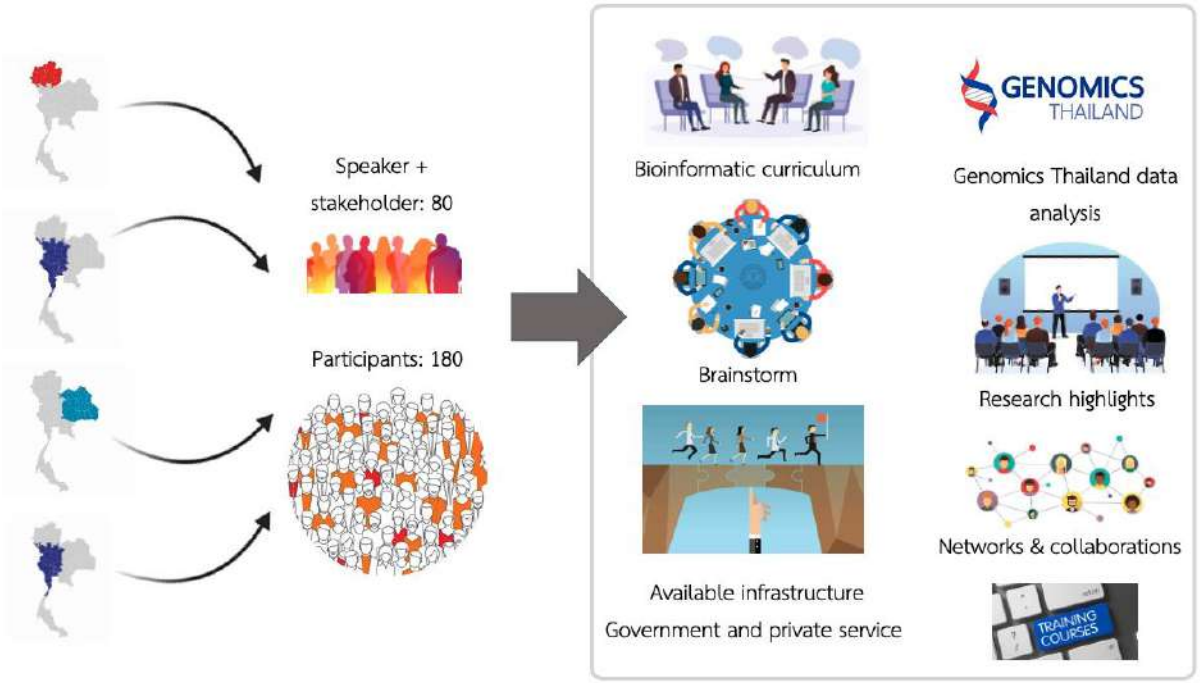
I am pleased to report that all the questions I posed have been addressed, and we are eager to present our findings to the government in the near future. This collaboration and collective effort reflect a shared dedication to fostering bioinformatics talent and innovation in Thailand, and I am humbled to have played a part in this meaningful endeavor.

Conclusion:

Current Output:

Challenges/Problems and Possible solutions:

Future plan:



Enhancing Skills and Increasing the Potential of Flavor Technologists to be Professional Flavorists in the Thai Flavor Industry

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Project duration: 3 years, from 1 August 2023 to 31 July 2026
Current progress: 25%

Abstract:

Currently food industries and food services in Thailand are almost entirely dependent on imported flavoring products, with import value exceeding five billion baht a year. Although, Thailand can produce a rich variety of raw materials for flavor and fragrance production, i.e., agricultural products of fruits, vegetables, and herbs. Some of these produce remains underutilized and certainly can be value added to produce high-value flavor and fragrance products for export as well as supplying the domestic market. One of the main reasons for the lack of growth in the domestic flavor and fragrance industry is an absence of specialized personnel such as flavorists. There is a need to incubate businesses and provide them with the proper technology, and to facilitate and promote research and development of expertise in the flavoring field. Research personnel in related fields in both the government and private sectors should receive more training. It is essential to build up Thai flavorists who understand the unique features of Thai cuisine and who will have the ability to select local ingredients and apply appropriate technology to make winning new flavor products that will support and strengthen the Thai food industry.

The present shortage of qualified flavorists and flavor industry specialists is unfortunately combined with a general lack of knowledge and understanding about this field and the technology required. Food Innopolis realizes the importance of building up knowledge and personnel for this sector, as up to now we have run Flavor Academy Network for more than four years to deliver the mission, hence we request support for the project “Enhancing skills and increasing the potential of flavor technologists to be professional flavorists in the Thai flavor industry.” The objective is to develop training sessions and workshops that match the needs of the Thai food industry and related industries. Appropriate training could serve to upskill and reskill research personnel working in the public and private sectors, and build up expert flavorists to work in the Thai food industry. Such training would also help develop internal experts and reduce reliance on foreign experts in the long run. Each generation could further transmit knowledge under the “train the trainers” format. This would be an efficient way to continuously provide a source of expert consultation and knowhow for food industry businesses and entrepreneurs.

Rationales/Problem statements:

Flavorings and fragrances are key food product ingredients that are important for commercial-level food production for the purposes of 1) fulfil some of the original flavors that might be lost during processing; 2) adding desired flavor to products that might be naturally bland or have some undesirable flavor; and 3) intensifying the flavor of certain products. For these reasons, the flavor industry plays an important role in the national food industry supply chain. At present, the flavor industry is growing continually, along with the food industry as a whole. The worldwide annual flavor and fragrance market is valued at 24.8 billion US dollars, or about 829 billion baht, and is growing at around 7% a year. The top three corporates in the global market are Givaudan, Firmenich, and IFF in succession.

Currently food industries and service in Thailand is almost entirely dependent on import of flavoring products with import value exceeding five billion baht annually. Although, is can be produced in Thailand from rich varieties of fruits, vegetables and herbs which remain underutilized. They could certainly be used to produce high-value export products and supplying the domestic market. One of the main reasons for the lack of growth in the domestic flavor and fragrance industry is an absence of specialized personnel such as flavorists.

Objectives:

1. To establish the flavor technology related training program in collaboration with experts/agencies abroad for personnel in academia and Thai food industry
2. To upskill research personnel from government and industrial sectors in flavor technology and flavor creation through training and workshop
3. To provide opportunity for potential personnel to be trained and become flavor creators and flavorists
4. To encourage application of knowledge and skills in developing of prototype flavors with Thai characteristics by using local raw materials.
5. To create a global network and collaboration in flavor technology via Flavor Academy activities

Progress/Findings/Results:

When the project has been approved, Flavor Academy team set up the meeting with ISIPCA representatives to for the discussion on the collaboration between Flavor Academy, Food Innopolis and ISIPCA and the details of a curriculum for the training that would be suitable for Thai's flavorings industry.

Now, we have developed a draft curriculum for 10-days joint training program in Bangkok, Thailand. This training program will be run by the experts from ISIPCA and Flavor Academy team. The target outputs from a 10-days joint training programs are:

1. Understanding the characteristics of flavor compounds in order to perform flavor creation
2. Understanding the process of flavor creation
3. Being able to formulate basic flavors in the laboratory with the assistance of expert flavorist
4. Being able to perform sensory evaluation of flavors and raw materials
5. Discovery of raw materials in food flavoring, including the different types of raw materials and their classification
6. Understanding the worldwide market of flavors, trends, and key players.

At the end of this training, each participant will receive a certificate of completion delivered by ISIPCA. Flavor Academy team has planned all activities that will be held in Year 1 as follows: 1) Introduction to aroma compounds through sniffing (15- 16 February 2024); 2) Training the trainer at ISIPCA, France (April, 2024) 3) 10-day joint training program in Bangkok, Thailand (May or June 2024)

In additional, Flavor Academy team will visit ISIPCA and flavor company in France during 19-25 November, 2023 to talking about our collaboration, finalize the training curriculum and preparation the training program in Bangkok.

Conclusion:

During the first 3 months of the project, all activities are proceed as a planned.

Current Output:

Challenges/Problems and Possible solutions:

Future plan:

Education and Development of Digital Learning Ecosystem Model area: Eastern Economic Corridor

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Project duration: 1 year, from 1 August 2022 to 30 November 2023
Current progress: 100%

Abstract:

The study of the digital learning ecosystem in the EEC area is the development project of learning management for workforce in the EEC. The project provides a significant learning ecosystem technology according to the workforce's needs. The project has created the system as a learning hub and tools for teachers, a vocational learning library for students, and developed online courses. Besides, board games on digital literacy were designed for general workforce. Online board games for primary careers; electrician mechanics and working in both studied areas to analyze local agencies' operational data. The pilot area of Bang Phra Subdistrict Municipality, Chonburi Province, has applied the results to develop suitable training in comprehensive healthcare for workforce. In Rayong Province, Industrial Estate Technical College has taken the results of the lesson plan to develop the teaching plans following the development of 21st-century skills in line with the needs of private sector.

Rationales/Problem statements:

1. What should a digital learning ecosystem be suitable for supporting the learning of Thai workforce?
2. How should operations with related local organizations to support workforce' learning through online?

Objectives:

1.To compare the learning ecosystem and the digital learning ecosystem that supports learning management for workforce aged over 15 years old

2.To develop a digital learning platform that supports learning under the context of the workforce aged over 15 years old and use the data from the platform to analyze and improve learning.

3. To develop 21st century skills curriculum for enriching career skills among workforce aged over 15 years old.

4.To create and develop a sample model of the digital learning ecosystem in the pilot area. by integrating and collaborating the Digital Learning platform with educational institutions and related organizations.

Findings:

This project emphasized the use of technology to connect the learning system for workforce. Two areas were selected as the studied area. First in Chonburi Province, including Bang Phra Municipality (Strategy and Planning Division, the Welfare Division, the Public Health Division, and Elderly School) and Chonburi Skill Development Institute. Second, Rayong Province was also the target. This province consists of leading partners, including the Rayong Skill Development Institute and Rayong Industrial Estate Technical College. The result shows that using technology as tool to support learning and management has successfully occurred. Learning providers and workforce in the pilot area met their needs. This project has also supported educational institutions, Provincial skill development, and companies to develop themselves through the DLEs HUB platform. This learning system could send learning material directly to individual learners via LINE Official. The developed DLEs HUB platform consists of systems and tools for supporting learning management for teachers or HR workforce called Teacher Hub. Self-paced learning systems, and tools called Learner Hub. This system has been connected to Thai MOOC, the system also connects the Portfolio system, and several skills assessment forms and online board games. The platform has established learning significant careers comprising 56 VDO clips, 14 occupations on YouTube (@eec-education channel). Moreover, there are other VDO clips from project's partners, infographics summarizing lesson content, and E-book.

According to the needs of workforce in the pilot area, the project has developed ICT Literacy course for Thai workforce. This course has been designed for on-site and online. students can learn through online classrooms or individual learners using the LINE Official.

The project and the partners have worked collaboratively to develop online board games suitable for workforce over 15 years old. This game encourages students to learn in the classroom and prepare for taking skill tests in the subjects of basic mechanics and electricians. Moreover, we created online board game title "Digital Danger" (ICT Literacy) for general workforce. As we know. It has been essential for their self-development.

Besides, from the study of workforce development, the cooperation between educational institutions and several private companies under the WiL project, which integrates learning with work, has created a prototype project. This project also developed an online skills assessment for Thai workforce consisting of 4 main assessment groups: 1) Thinking and Decision-Making Skills, 2) Language and Communication Skills, 3) Technology Skills and 4) Interpersonal Skills.

This project provided analyses on vocational training data of the Welfare Division, record of Heath Data (43 Files), Strategic and Budget planning Division. The results of these analyses lead the planning for the development of career promotion in the next fiscal year and planning to prevent and promote the healthcare of workforce in the area. In Rayong Province, the project analyzed data on the teaching plans of Rayong Industrial Estate Technical College to explore 21st-century skills. The results lead to the development of plans that promote 21st-century skills. This result shares significant guidelines in line with the skills needed by the private sector.

Conclusion:

Connecting the digital learning ecosystem reduces learning time and places limitations. The system encourages workforce to learn according to their interests and develop their skills with their needs. The system design should be connected to teachers' and students' learning support systems. The system includes a self-evaluation system and provides direct individual answers. In addition, the learning ecosystem must promote and support the work of the local government and private agencies. In organizing learning, driving operations with data analysis plays an important role that local agencies or organizations should focus on to improve the present work.

Current Output: prototype:

A digital learning ecosystem consists of 1) DLEs HUB platform connecting to learning management support systems and self-paced learning. The system provides services to workforce in prototype areas and general workforce in other areas. 2) Digital literacy courses with board games that can be learned through the online and on-site systems. Moreover, online career board games are provided, 3) Online skills assessments, and 4) Areas as a model for promoting digital learning with the creation of guidelines for expanding the digital learning space to other areas.

Challenges:

Expanding and developing DLEs HUB is one of the challenges. However, we should mind about learner needs appropriately and effectively. In addition, the project must cope with rapid changes in technology. At the same time, the system must consider the security of data and personal information. In addition, creating learning content must consider suitability, interests, age, and goals. Therefore, learning interactions and information sharing must be integrated to the digital learning ecosystem. Notably, the development of the digital learning system must be supported by policies and organizations. This solution will expand the learning to its full potential.

Future plan:

1. The project should expand the application of the DLEs HUB platform to other areas.
2. Expanding the connection of DLEs HUB platform with other learning ecosystems.
3. The project should develop a portfolio system that meets the needs of Thai workforce and private sector.
4. Developing and promoting the skills assessment system to assess specific skills for different occupations.

5. The project should promote results of data analysis for planning learning management, including workforce development in prototype areas.

Developing Innovations to Enhance the Production and Development of Teachers Based on the Concept of Social Engineers Using the Community as a Base

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Project duration: 1 year, from 1 August 2022 to 31 July 2023
Current progress: 90%

Abstract:
The research subject “developing innovations to enhance the production and development of teachers based on the concept of social engineers using the community as a base” has developed an innovation “Teacher production and development based on the community-based social engineer concept” at Chiang Mai Rajabhat University and evaluated the efficiency of the innovation according to the 80/80 level criteria. The results of the synthesis of innovation lessons are in the form of "CPRD", a process in which students and teachers use soft skills to create innovations to help solve community problems and strengthen communities with a 4-step innovation system, which are: (1) C = Cooperate: Student teachers can cooperate with groups and communities. (2) P = Plan: Student-teachers can plan and work together towards goals through positive communication. (3) R = responsibility: teacher students are responsible for their roles and (4) D = Develop: Student teachers can bring their findings from the development to the public, where innovation in such form can raise the level of production and develop teachers and be used as a method for expanding and transferring the innovation model of teacher production and development based on the community-based social engineer concept to the Rajabhat University groups.

Rationales/Problem statements:
Key skills for leaders and modern workers (soft skills) are critical thinking and problem solving, creativity and innovation, communication, information and media literacy, cross-cultural understanding and collaboration, teamwork, and leadership. These skills will help people work effectively with others. and affect the success of the work as the organization hopes (Nonglak Isaro, 2021). But there was a problem: “soft skills” are more difficult to measure. It is highly abstract because it is a skill that arises from a person's intrinsic attributes. Chiang Mai Rajabhat University is committed to producing, developing teachers, and local development with the concept of social engineering by developing important skills of leaders and modern workers. Soft Skills focuses on designing and testing an innovative system for organizing learning activities for Chiang Mai Rajabhat University students. to develop and evaluate performance. As well as synthesize lessons learned about innovation in enhancing production and teacher development based on the community-based concept of social engineers. To be used as a guideline for expanding results and transferring innovations as prototypes of production and teacher development to Rajabhat University groups.

Objectives:
1. To innovate in elevating production and developing teachers based on the concept of social engineering by utilizing the community's base.
2. To expand the impact and implement innovative prototypes for the production and development of teachers based on the concept of social engineering by utilizing the communities’ base of Rajabhat University groups.

Progress/Findings/Results:
Results of developing and evaluating the efficiency of innovation, production enhancement,

and teacher development based on the community-based social engineer concept It meets the 80/80 criterion, indicating that the innovation is effective. It was found that the results of finding the efficiency of innovation, production enhancement, and teacher development according to the community-based social engineer concept of Chiang Mai Rajabhat University Efficiency: 83.33/89.58, meeting the specified criteria: 80/80. Teacher-Student Competency Assessment Results By comparing the four soft skills before and after using the training package based on the concept of social engineers using community as a base for teacher students of Chiang Mai Rajabhat University. This shows the efficiency of teacher production and development innovation based on the community-based social engineer concept. The results of the synthesis of lessons learned from the innovative prototype of social engineer-based teacher production and development based on the community-based concept consisted of (1) a training plan for teacher production and development based on the community-based social engineer concept and (2) a teacher competency scale. According to the community-based social engineer concept, a total of 8 plans took 44 hours. The CPRD Model in the learning activity plan is a learning management process that focuses on giving students or learners experiences through action through thinking, problem solving, and coordinating work. With the community as a learning base, the details of the procedure are as follows: **Step 1)** C = Cooperate **Step 2)** P = Plan **Step 3)** R = Responsibility **Step 4)** D = Develop: This means applying the acquired findings to improve, develop, and change to reach the goals. be able to present the results of concept development to the public and give opportunities for discussion and exchange of ideas. The CPRD model is an innovation system that uses a collaborative process to plan activities responsibly to develop students' soft skills in order to develop communities with participation. Therefore, it can effectively raise the level of production and develop teachers because of four soft skills, namely thinking skills and communication skills. Coordination skills and innovation skills are able to develop through hands-on activities with active learning and community visits to solve community problems. Therefore, it can raise the level of production and development of teachers.

Conclusion:

The soft skills development of student teachers consists of four skills: thinking skills, communication skills, coordination skills and, innovation skills. Through action with community participatory active learning (PAR) using a progressive activity plan of the CPRD model. Therefore, it can raise the level of production and develop teachers effectively according to the following innovation systems.

Current Output: Publication 1 Paper **(**Multicultural Education, Volume 9**,** Issue 10, 2023)

Future plan:

Carry out activities Summarize/analyse to prepare a complete report. and evaluate the use of innovations and methods for developing local curricula. Local wisdom, educational games, community products using innovation It will result in sustainability in solving spatial problems and expand the impact and implement innovative prototypes for the production and development of teachers based on the concept of social engineering by utilizing the communities' base of Rajabhat University groups.

The Development of Reinforcement System to Drive Teacher Training Process for Faculty of Education, Rajabhat Universities

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Project duration: 1 year, from 1 August 2022 to 31 September 2023
Current progress: 60%
Abstracts:

Research project on the development of reinforcement system to drive teacher training process for Faculty of Education, Rajabhat University, with 4 specific objectives, including: 1) to develop a network management system for teacher training; 2) to develop a system for raising the potential of teachers in the teacher training process; 3) to develop a system for raising the potential of student teachers; and 4) to develop a monitoring and evaluation system for the teacher training process. The research is conducted in 38 faculties of education nationwide. The progress report are summarized as follows:

1. The network management system for teacher training consisting of 3 key components: 1) input factors, including information/data and management mechanisms; 2) a 4-step process, including planning, implementation, monitoring and evaluation; and improvement; and 3) the outcomes of the system, including the university's teacher education on policy that aligns with the local context.

2. The development of a system for raising the potential of teachers in the teacher training process has been carried out, focusing on the development of 7 learning modules that emphasize the professional competencies of teachers as specified by the Teacher Council, in order to enhance the knowledge and professional competencies of teachers in the teacher training process.

3. The development of a system for raising the potential of student teachers has been implemented, identifying key competencies that should be developed for student teachers in collaboration with graduate and teacher council organizations, totaling 17 competencies.

4. The development of the monitoring and evaluation system for the teacher training process has been initiated, creating assessment tools for the 17 competencies of student teachers and currently in the process of checking tools quality.

Rationales/Problem statements:

Rajabhat University has made changes to its Bachelor of Education curriculum since 2019. However, there are still challenges and limitations in implementing the curriculum.

The research and development project to improve the quality of teacher education has suggested solutions in three areas 1) curriculum development, 2) creating courses that promote high-quality teachers 3.setting clear goals for the teacher education curriculum. The project emphasizes the importance of teaching quality and coaching, the need for clear regulations and processes for professional training. It highlights the significance of selecting and developing mentor teachers with expertise in learning management and research and also the importance of reviewing and improving the teacher education process based on evaluations and research results. The focus is on producing teachers who meet the knowledge

standards set by the Teachers Council and possess knowledge in content, learning management, teacher characteristics, and community relationships. The university has expanded the competencies required for teacher graduates to a total of 17. Therefore, it is necessary to develop the teacher production system within the Faculty of Education at Rajabhat University, particularly in terms of management, faculty development, student development, and monitoring and evaluation systems. This will enable all universities to use it as a guideline for developing students' competencies in line with the future curriculum., it is necessary to develop the teacher production system within the Faculty of Education at Rajabhat University, particularly in terms of management, faculty development, student development, and monitoring and evaluation systems. This will enable all universities to use it as a guideline for developing students' competencies in line with the future curriculum.

Objectives:

1. To develop a network management system in the teacher training process of the Faculty of Education, Rajabhat University
2. To develop a system for raising the potential of teachers in the teacher training process of the Faculty of Education, Rajabhat University
3. To develop a system for raising student potential in the teacher training process of the Faculty of Education, Rajabhat University
4. To develop a system for monitoring and evaluating the teacher training process of the Faculty of Education, Rajabhat University

Progress/Findings/Results:

1. The development of a network management system has been initiated, consisting of 3 components as follows:
    1) Import factors, including
        1.1 information and ideas used for network management.
        1.2 Mechanisms for network management, including the Faculty of Education's deans' council, regional networks, the Faculty of Education, and supporting academic work committees.
    2) The process consists of four steps: planning, implementation, monitoring and evaluation, and improvement.
    3) The system's outcomes include the university's teacher education policies that align with the local context.
2. The development of a system for raising the potential of teachers in the teacher training process in the teacher training process at the Faculty of Education, Rajabhat University, involve the implementation of a framework for developing teachers and developing teacher development courses, as follows:

    1) The framework for developing teachers consists of 5 components, which are:

Component 1: the curriculum focuses on competency-based development, with the goal of developing teachers according to the STRONG TEACHER framework of the Royal Rajabhat University.	**Component 2:** the curriculum contains essential content that is necessary for the professional development of teachers. It can be used to enhance the skills and knowledge of teachers who do not have a formal education degree or to provide re-skilling/up-skilling training for teachers in the field of education. It is also beneficial for teachers responsible for the curriculum or university professors who are interested in this field.

Component 3: the curriculum specifies the content as separate modules. Each module can be taken independently. Trainees who are seeking re-skilling/up-skilling can choose to train in modules according to their interests.	**Component 4:** flexibility in training format, training schedule, and assessment and evaluation methods according to the context of each university.
Component 5: the curriculum is designed to include 3 types of activities, namely active training, on the job training, and school visiting.	

2) The teacher development program consists of 7 learning modules that align with the competencies specified in the Teacher Professional Standards (Version 4) of the Ministry of Education in 2019. The program requires a total of 92 hours, divided into 72 hours for knowledge and subject-specific professional development for teachers, and 20 hours for teaching practice in educational institutions.

Regarding the implementation of the program, it was found that the faculties of education in all 38 Rajabhat Universities have designed the implementation of the teacher development curriculum in four approaches: active training through on-site/online training, self-study through online platforms, on-the-job training, and learning through school visits.

3. The development of a system for raising the potential of student teachers has been implemented, identifying key competencies that should be developed for student teachers in collaboration with graduate and teacher council organizations, totaling 17 competencies. For graduates of Rajabhat University's Professional Teacher program (PTRU). These competencies include professional teaching practice, leadership and interpersonal skills, classroom management, teamwork, digital technology utilization, strategic communication, teacher personality and attitude, volunteerism, public spirit, media literacy, facilitating learning, assessment and evaluation, application of the sufficiency economy philosophy, curriculum design and development, good citizenship, integration of science into teaching, and educational innovation and teacher spirit.

4. The development of the monitoring and evaluation system for the teacher training process of the faculties of education in Rajabhat Universities involve the creation of assessment tools for evaluating the 17 competencies of student teachers from their first to fourth year. This was done by analyzing the foundational curriculum, the standards of the Teachers' Council, and defining indicators of student characteristics to cover all 17 competencies. Currently, the quality of the assessment tools is being reviewed, and they will be tested for validity and reliability to create a complete and comprehensive assessment tools in the future.

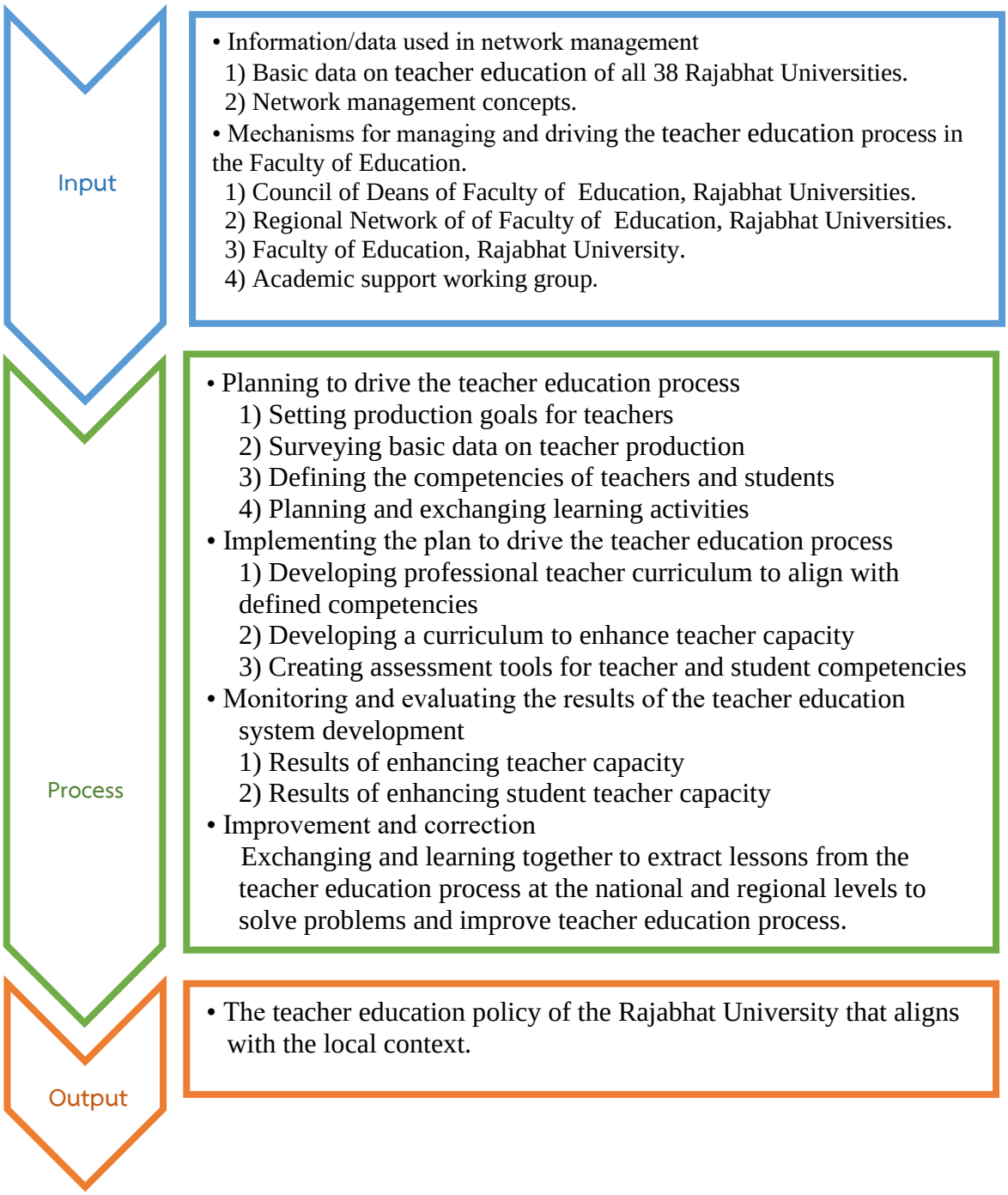
Conclusion:

The research project aims to develop reinforcement system to drive teacher training process for Faculty of Education, Rajabhat University. The research is conducted at 38 faculties of education nationwide. The progress report are summarized as follows: 1) The development of the network management system has been initiated, consisting of 3 components: input factors, processes, and outputs; 2) The development of a system for raising the potential of teachers in the teacher training process has been carried out, focusing on the development of 7 learning modules that emphasize the professional competencies of teachers as specified by the Teacher Council.; 3) The development of a system for raising the potential of student teachers has been implemented, identifying key competencies that should be developed for student teachers in collaboration with graduate and teacher council organizations, totaling 17 competencies. 4) The development of the monitoring and evaluation system for the teacher training process has been initiated, creating assessment tools for the 17 competencies of student teachers and currently in the

process of checking tools quality.

Current Output:

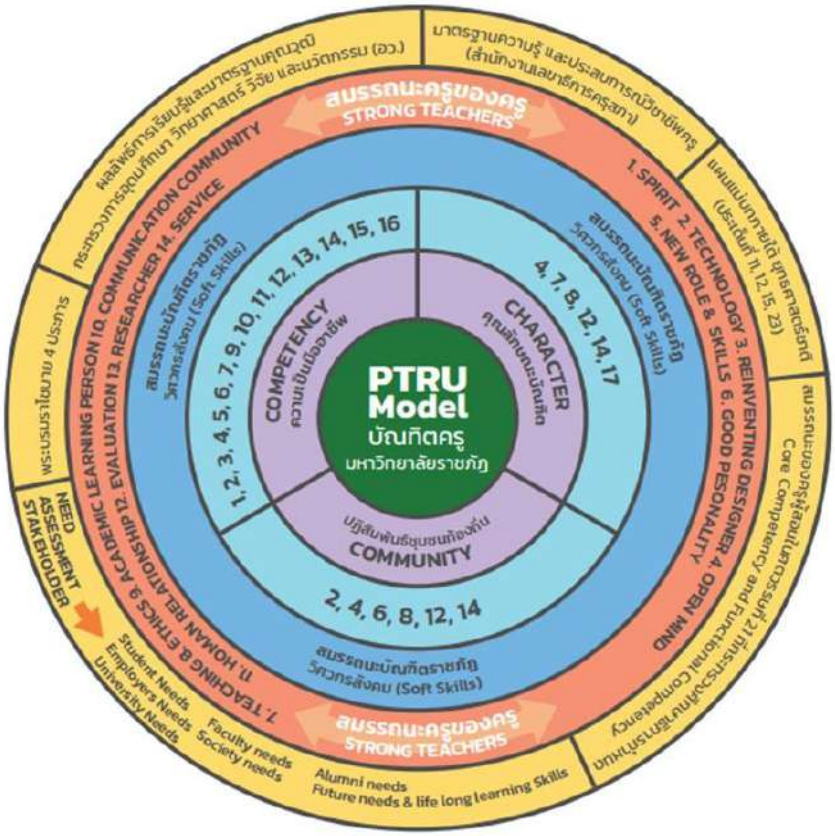
1. Draft of the management system for the teacher education network of the Faculty of Education, Rajabhat University.



2. The professional teacher development course consists of 7 learning modules, with a total development time of 92 hours. It is divided into 72 hours of knowledge and professional subject development, and 20 hours of teaching practice in educational institutions.

Module	Period (hours)
1. Smart Teachers	12
2. Smart Communication	12
3. Smart Teaching	12
4. Smart Researcher	12
5. Smart Innovator	12
6. Smart Change Agent	12
7. Teacher Practicum	20

3. Competencies of a graduate teacher for Rajabhat university.



Challenges/Problems and Possible solutions:

Challenges/ Problems	Possible Solutions
• The delay in implementing the faculty and student teacher development system may be due to meetings held by the Rajabhat University Council and the Council of Deans of Education, which have decided to review the competency of student teachers as previously set in the year 2019. This is to ensure clarity and understanding among all 38 universities.	• The meeting of the Council of Rajabhat University and the Council of Faculty of Education, Rajabhat University organized a project for practical collaborative development in producing graduates and developing basic teacher competencies for the 21st century. This took place from January 31st to February 2nd, 2566, and was approved by the Secretary-General of the Basic Education Commission and the Secretary-General of the Teachers' Council on February 13th, 2566. The official announcement was made on February 14th, 2566, which included the designation of 17 key competencies for graduates of Rajabhat University.
• The mission to develop teachers nationwide according to the cooperation agreement between the Rajabhat University and the Office of Basic Education Commission, which had to be urgently implemented from October 2566 to March 2567, resulted in delays in driving the development process of teachers and student teachers in the research project.	• The researchers will collaborate with the Faculty of Education Deans Council in planning and implementing a system to enhance the capacity of teachers and students within the second semester of 2566.

Future plan:

1. Development of a manual for using the teacher and student capacity building system.
2. Analysis of the quality of the teacher's student competencies assessment tools, consisting of 17 competencies.
3. Development of an information system to monitor the evaluation of the teacher education process at the University.
4. Evaluation of the progress of the development of the Faculty of Education's teacher education system.
5. Extraction of lessons and selection of best practices in the regional teacher education process.
6. Synthesis of the teacher education process system to present at the meeting of the Council of Deans of the Faculty of Education, Rajabhat Universities.

Lifelong Learning through Hybrid-Edutainment System with Online Games and Learning Kit for Novel PV-agricultural Technology

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Project duration: 1 year, from 25 August 2022 to 31 July 2023

Current progress: 80%

Abstract:

Thailand has integrated lifelong learning into its national strategic framework to prepare its students for rapid changes in various sectors. Central to this initiative, research has been conducted on educational strategies that leverage the 'Hybrid-Edutainment' model, particularly through educational games. These games are specifically designed to not only engage students but also to enhance their understanding of modern technologies in electrical engineering and contemporary agricultural practices. The focus is on fostering a deeper comprehension and practical skills among students and educators, which are essential for navigating the complexities of today's technology-driven agricultural landscape. This educational approach aligns with the need to develop a future-ready workforce that is well-versed in new technologies and ready to innovate in the field of agriculture.

Rationales/Problem statements:

In Thailand's pursuit of national development through lifelong learning, there is a pressing need to address the educational gap in understanding and applying modern electrical technologies and advanced agricultural methods among students. While traditional educational models have limitations in fostering practical skills, the challenge lies in devising an engaging and effective learning framework. The 'Hybrid-Edutainment' approach, integrating educational games, offers a solution, yet its effectiveness in enhancing the technological and agricultural acumen of students remains to be validated through focused research. This underscores the need for innovative educational tools that not only captivate students' interest but also equip them with the requisite competencies for a technologically advanced workforce in agriculture.

Objectives:

1) To develop a lifelong learning curriculum through a Hybrid-Edutainment system utilizing online games, along with a learning module for the installation, inspection, and maintenance of solar energy technology for modern agriculture.
2) To enhance lifelong learning skills specific to the installation, inspection, and maintenance of solar energy technology in modern agriculture.

Progress/Findings/Results:

Lifelong Learning course through hybrid entertainment system (Hybrid-Edutainment) with online games and learning kits on solar energy technology for modern agriculture, designed to suit the context of learners according to the Tailor-made concept. Online games and learning kits on solar energy technology for modern agriculture are consistent with the learning content by including student evaluations through tests and questions in online games. This makes it fun for students to learn and search for answers so they can pass levels in the game. Developed online games will be one process that will help reduce investment in learning equipment, reducing costs and increasing the accessibility of learning energy technology for agriculture more easily. Once students are able to understand the learning

content expected from the game, they can move on to the stage of experimenting with the real equipment for learning about solar energy technology for modern agriculture. In addition, teachers can use the data processed from the database to be useful in measuring individual student evaluations as well as conducting research in the classroom to create work to raise their own academic status.

Conclusion:

This work aims to develop a lifelong learning curriculum through a Hybrid-Edutainment system utilizing online games, along with a learning of solar energy technology for modern agriculture. This work also enhances lifelong learning skills specific to the installation, inspection, and maintenance of solar energy technology in modern agriculture. The “Smart Kru” game is specifically designed to not only engage students but also to enhance their understanding of modern technologies in agricultural practices. This educational approach aligns with the need to develop a future-ready workforce that is well-versed in solar technologies and ready to innovate in the field of agriculture.

Current Output:

API big data 1 software, Technology prototype 10 technology, Demo gameplay 1 application.

Challenges/Problems and Possible solutions:

One major challenge in creating educational games is to avoid making the content feel imposed upon the students, as the games need to be both enjoyable and informative. A possible solution to this issue is the implementation of adaptive learning algorithms, which can adjust the complexity and the presentation of information according to the individual's pace and progress. Additionally, collaboration between skilled game developers and educational experts is crucial to ensure a harmonious balance between gameplay and learning outcomes, thereby facilitating an engaging and effective educational experience.

Future plan:

The future plan involves the widespread adoption of the educational game across Thailand to leverage diverse usage data for behavioral analysis. This data will be instrumental in refining research methodologies and game content, thereby improving its educational efficacy and engagement. Such enhancements will solidify the game's role in advancing Thailand's lifelong learning initiatives in modern agricultural and technological education.

High-Energy Particle Physics and High-Energy Astrophysics Manpower Development through Collaboration with International Institutions.

Pairash Thajchayapong, Chadamas Thuvasethakul*, Umaratchani Kaewbutta, Ruetai Chongsrid, Yaowalak Khonklong, Waraporn Nuntiyakul, Achara Seripienlert, Thirasak Panyaphirawat, Sunisa Wonglek, Pankamon Sornsuwan, Renuka Arnub
Information Technology Foundation under the Initiatives of H.R.H. Princess Maha Chakri Sirindhorn (Princess Sirindhorn IT Foundation: PSIT)

Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 90%

Abstract:

Her Royal Highness Princess Maha Chakri Sirindhorn has a keen interest in science and technology and its impact on development. She has visited many world-leading research institutes in many countries to observe and learn new knowledge on technological advancement. Such visits have opened doors and created opportunities for Thai scientists to participate in programs and/or activities organized or performed by those institutes, including participating in research work with world-leading scientists. In the field of physics, Her Royal Highness Princess Maha Chakri Sirindhorn visited world-class research institutes that conducts research on high-energy particle physics and high-energy astrophysics as follows:

(1) The European Organization for Nuclear Research (CERN)
(2) Deutsches Elektronen Synchotron (DESY)
(3) GSI Helmholtz Center for Heavy Ion Research (GSI)
(4) IceCube Neutrino Observatory (IceCube)

Following her visits, all four institutes have offered opportunities for Thai scientists to participate in the Summer Student Program that they organize every year until now. In addition, CERN has offered opportunity for Thai teachers to participate in their Science/ Physics Teacher program. Through these programs, Thai scientists have opportunities to access information and use large-scale scientific facility/equipment, such as particle accelerators, particle detector, super computer etc., that cannot be purchased or built in Thailand. It also develops science teaching for Thai youth at various levels, inspiring the new generation to be interested in learning about high-energy particle physics and high energy astrophysics. Altogether, the program helps to create personnel to support cutting-edge technology or innovation and/or other future technologies which are important to the country.

Such manpower development program in Thailand is carried out by the Information Technology Foundation under the Initiative of Her Royal Highness Princess Maha Chakri Sirindhorn or Princess Sirindhorn IT Foundation (PSIT), in collaboration with many academic partners including the Synchrotron Light Research Institute (Public Organization), National Science and Technology Development Agency, National Astronomical Research Institute (Public Organization) and Chiang Mai University.

In 2023, these four research institutes presented award scholarships to Her Royal Highness Princess Maha Chakri Sirindhorn to select students and teachers in science (physics, biology, computer science, etc.) and engineering fields to participate in 6 summer activities. Presently, the following results have been achieved:

1. Human resource development: A total of 14 persons, including:

(1) Twelve students (10 undergraduates, 1 master's, and 1 doctoral) have developed and have increased scientific and research skills.

(2) Two high-school science teachers have developed and have increased scientific and science teaching skills, particularly in particle physics.

2. Activities to disseminate particle physics knowledge

The basic particle physics training project by the Institute for the Promotion of Teaching Science and Technology (IPST) in collaboration with Chulalongkorn University held on 29-30 April 2023 at the Faculty of Science, Chulalongkorn University. There were 161 people, including 9 researchers, 12 students, 17 teachers, 117 high school students and 15 staff, participating in the training to prepare for academics related to basic particle physics and work in the field of elementary particles.

Rationales/Problem statements:

The PSIT Foundation responds to the initiative of Her Royal Highness Princess Maha Chakri Sirindhorn to build academic cooperation with world leading research institutes. Such cooperation provides opportunities for Thai scientists to participate in research work with scientists and researchers at those institutions in the field of high energy particle physics and high energy astrophysics. Presently, there is academic cooperation with four leading research institutes as follows:

1) The European Organization for Nuclear Research (CERN), located in Geneva, Switzerland
2) Deutsches Elektronen Synchotron (DESY), located in Hamburg and Zeuthen, Federal Republic of Germany.
3) GSI Helmholtz Center for Heavy Ion Research (GSI), located in Darmstadt. Federal Republic of Germany
4) IceCube Neutrino Observatory (IceCube), located at the Amandsen-Scott South Pole Station in Antarctica. (Amundsen–Scott South Pole Station)

All four institutes have offered opportunities for Thai scientists to participate in the Summer Student Program that they organize every year until now. In addition, CERN has offered opportunity for Thai teachers to participate in their Science/Physics Teacher program. Through these programs, Thai scientists have opportunities to access information and use large-scale scientific facility/equipment, such as particle accelerators, particle detector, super computer etc., that cannot be purchased or built in Thailand. It also develops science teaching for Thai youth at various levels, inspiring the new generation to be interested in learning about high-energy particle physics and high energy astrophysics. Altogether, the program helps to create personnel to support cutting-edge technology or innovation and/or other future technologies which are important to the country.

This Project (High-Energy Particle Physics and High-Energy Astrophysics Manpower Development through Collaboration with International Institutions) will develop students (undergraduate and graduate students) and science teachers by providing opportunity to participate in the summer program organized by the 4 research institutes as follows.

1) CERN Summer Student Program (Switzerland)
2) CERN High School Teacher Program (Switzerland)
3) CERN International Teacher Week Program (Switzerland)
4) DESY Summer Student Program (Germany)
5) GSI/FAIR Summer Student Program (Germany)
6) IceCube Summer Student Program (United States)

Summer student project is an important activity that the world's leading research institutes organize continuously every year to allow students from around the world to have the opportunity to participate in the program every summer. Emphasis is placed on students pursuing bachelor's and master's degrees in physics, computers, and engineering and mathematics. Throughout the 8-week period, students will learn about the mission of research institutes from the past to the present, future research and development guidelines for particle

physics and astrophysics , as well as participating in scientific and engineering research, such as the design of particle detectors and analysis of data obtained from particle detectors, simulating particle collisions in a particle detector, database system improvements, analysis of data obtained from experiments and comparison with theories of physics etc.. In addition to academic lecture activities and visits to various laboratories within these research institutes, students will have the opportunity to work with some of the world's leading scientists and have the experience of living with students from various fields of study from different cultures.

CERN High School Physics Teacher Program is a project organized by CERN since 1998 to develop the teaching of physics, especially particle physics for high school students, to enhance understanding of science and develop students' skills in high technology and to promote students' love of science. Experiences are shared among teachers who have received international training.

The benefits of participating in these programs are inspiration for further study and opportunities for students to practice real research. This leads to the creation of quality scientists, engineers and innovators in the future. As for the benefits from participating in science teacher activities, high school science teachers are encouraged and trained to be able to transfer knowledge gained from world-class research institutes to students and be able to create teaching materials related to high energy physics and astrophysics that can actually be used in the classroom.

Cooperation with world's leading research institutes gives Thailand an opportunity to select physics students studying in Thailand and high school physics teacher to participate in the summer student program and the summer teacher program since 2010. This later resulted in many forms of collaborative activities, including the dissemination of knowledge about particle physics in Thailand, sending Thai high school students for a short-term visit at CERN, sending master's and doctoral students and researchers to conduct research at leading research institutes. Later in 2012, Thai universities signed a cooperation agreement with various CERN experiments, which helps to enhance the research work and the visibility of Thai scientists in the international arena.

Currently, there are no less than 11 agencies in Thailand that have cooperation in high-energy particle physics and high-energy astrophysics with these four world-leading research institutes, including the Synchrotron Light Research Institute (Public Organization), National Science and Technology Development Agency, National Astronomical Research Institute (Public Organization), Thailand Institute of Nuclear Technology (Public Organization), Chulalongkorn University, Suranaree University of Technology, Mahidol University, King Mongkut's University of Technology Thonburi, Center of Excellence in Physics, Hydro-Informatics Institute (Public Organization) and the Digital Government Office (Public Organization).

Objectives:

To enhance the ability of the workforce in the field of high-energy particle physics. and high-energy astrophysics through collaboration with the world's leading international institutions with particular objectives as follows:

1. Inspire students to continue studying and doing research in high energy physics. and high energy astrophysics.
2. Create opportunities for students to exchange knowledge with students around the world and gain direct research experience from scientists and/or researchers at world-class research institutes.
3. Allow students to apply the knowledge gained as a guideline for their own development and preparation for becoming a scientist, researcher, or engineer in the future.

4. Provide opportunities for high school science teachers to build networks and exchange knowledge and collaborate with science teachers from around the world.
5. Create correct understanding in teaching particle physics and astrophysics to science teachers and to further disseminate knowledge about high-energy particle physics to students.
6. Allow science teachers to learn about creating teaching materials that are easy to understand. and can actually be used.

Progress/Findings/Results:

In 2023, these four (4) research institutes presented award scholarships to Her Royal Highness Princess Maha Chakri Sirindhorn to select students and teachers in science (physics, biology, computer science, etc.) and engineering fields to participate in 6 summer activities organized by these research institutes. PSIT has worked with academic partners to select Thai students and teachers to participate in those programs.

Presently, the following results have been achieved:

1. Human resource development: A total of 14 persons, including:

(1) Twelve students (10 undergraduates, 1 master's, and 1 doctoral) have developed and have increased scientific and research skills.

(2) Two high-school science teachers have developed and have increased scientific and science teaching skills, particularly in particle physics.

Details are as follows:

Activities	Student			Teacher (high school)	Total
	Bachelor's degree	Master's degree	Doctorate degree		
1. CERN High School Teacher Program and CERN International Teacher Week Program at Switzerland	-	-	-	2	2
2. CERN Summer Student Program at Switzerland	4	-	-	-	4
3. DESY Summer Student Program at Germany	4	-	-	-	4
4. GSI/FAIR Summer Student Program at Germany	1	1	-	-	2
5. IceCube Summer Student Program at United States of America	1	-	1	-	2
total	10	1	1	2	14

In 2023, there were 12 students participating in the Summer Student Program and 2 teachers participating in the Summer Teacher Program, a total of 14 people as follows:

1) CERN Summer Student Program: the 4 students participated in the program from 3 June 2023 to 27 August 2023.

1.1) Mr. Paramott Bunnjaweht

- Bachelor of Science, Faculty of Science, Chulalongkorn University
- Research topic: tt-H Events Classification with Graph Neural Networks in 2L(SS) + 1τhad Channel

1.2) Mr. Ek-ong Atthaphan

- Bachelor of Science, Institute of Science, Suranaree University of Technology
- Research topic: Building of CRAB Spark Data Pipeline

1.3) Mr. Purinut Lersnimitthum
- Bachelor of Engineering, Faculty of Engineering, Chulalongkorn University
- Research topic Structural Analysis of The MTLs Supports for ATLAS

1.4) Mr. Thanapong Sommat
- Bachelor of Engineering, Faculty of Engineering, Sirindhorn International Institute of Technology Thammasat University
- Research topic: Formal Verification of Neural Networks

2) DESY Summer Student Program: the 4 students participated in the program from 18 July 2023 to 7 September 2023.

2.1) Mr. Nuttawat Khammata
- Bachelor of Science, Faculty of Science, Chiang Mai University
- Research topic: Analysis of ultra-short XUV FEL pulses

2.2) Mr. Chattamas Manoworakul
- Bachelor of Science, Faculty of Science, Mahidol University
- Research topic: Recyclable Cellulose-Based Solar Cells Using Fully Sprayed All-Layered Material

2.3) MissThunrada Sukwiboon
- Bachelor of Science, Faculty of Science, Mahidol University
- Research topic: X-ray optics through additive manufacturing

2.4) Mr. Punnawich Chokeprasert
- Bachelor of Science, Faculty of Science, Chulalongkorn University
- Research topic: SMEFT Studies for ttH(bb) Channel

3) GSI/FAIR Summer Student Program: the 2 students participated in the program from 24 July 2023 to 14 September 2023.

3.1) Miss Yaowaluk Buanill
- Bachelor of Science, Institute of Science, Suranaree University of Technology
- Research topic: Electric Field Computation from Particle Distributions: A Study of Boundary Effects

3.2) Miss Nantana Monkata
- Master of Science, Faculty of Science, Khon Kaen University
- Research topic: Evolution of activity during and after the implantation of radioactive ions

4) IceCube Summer Student Program: the 2 students participated in the program from 1 June 2023 to 31 July 2023.

4.1) Miss Yanee Tangjai
- Doctorate Degree, Faculty of Science, Chiang Mai University

4.2) Miss Wassachon Kammeemoon
- Bachelor's degree, Faculty of Science, Mahidol University

5) CERN High School Teacher Program

5.1) CERN International High School Teacher Program
- Miss Patcharaporn Bunkitti
  Princess Chulabhorn Science High School Chonburi, Chonburi Province
  participated in the program on 2 – 15 July 2023

5.2) CERN International Teacher Week Program
- Miss Waritsara Watcharaphanit
  Phimai Wittaya School, Nakhon Ratchasima Province
  participated in the program on 6-19 August 2023

2. Activities to disseminate particle physics knowledge

The basic particle physics training project by the Institute for the Promotion of Teaching Science and Technology (IPST) in collaboration with Chulalongkorn University held on 29-30 April 2023 at the Faculty of Science, Chulalongkorn University. There were 161 people, including 9 researchers, 12 students, 17 teachers, 117 high school students and 15 staff, participating in the training to prepare for academics related to basic particle physics and work in the field of elementary particles.

Conclusion:

In 2023, a total of fourteen (14) persons (12 students and two teachers) have participated in 6 summer activities with all 4 institutions, resulting in statistics of Thailand participation in various activities as follows:

Summer Camp Program	Statistics of participants*			Participants in 2023		Total (Person/Batches)
	start year - current year	number of batches	number of Participants (Person)	Plan (Person)	Result (Person)	
1. CERN High School Teacher Program and CERN International Teacher Week Program in Switzerland	2553 – 2565	12 batches	24	2	2	26/13
2. CERN Summer Student Program in Switzerland	2553 - 2565	13 batches	37	4	4	41/14
3. DESY Summer Student Program in Germany	2546 – 2565	19 batches	49	4	4	53/20
4. GSI/FAIR Summer Student Program in Germany	2560 - 2565	4 batches	8	2	2	10/5
5. IceCube Summer Student Program in USA	2565	1 batch	2	2	2	4/2
total	120 person			14	14	134 persons

Note ** Statistics on project participation (2010-2022) include a total of 120 people from more than 13 educational institutions across the country.*

Current Output:

Output / Outcome	Detail of Output / Outcome
1. Human resource development - Bachelor's degree students - Graduate students	Students develop and have increased scientific and research skills from participating in research with leading research institutes abroad, totaling 12 people as follows: - 10 undergraduate students - 1 master's degree student - 1 doctoral student
2. Human resource development - Science teacher	Two (2) science teachers at the high school level have developed and have increased scientific and science teaching skills, particularly in particle physics, from participating in workshops. They learn techniques in teaching particle physics and learn how to develop teaching media about particle physics through programs at CERN.

3. Engagement activities	Organize basic particle physics training on 29-30 April 2023 at the Faculty of Science. Chulalongkorn University. There were 161 people receiving training to prepare for particle physics, high energy physics, physics of particle accelerators and quantum physics.

Challenges/Problems and Possible solutions:

Difficulties in collecting data on project outcome and impact because the project will send students to participate in summer programs with international research institutes. The direct project output will be the number of students participating in these programs. During the programs, undergraduate students will learn new knowledge through participation in summer camps and perform assigned tasks in the form of short-term operations. For graduate students (Master's or Doctorate degree), they will gain additional knowledge from various summer camps and have the opportunity to participate in research through various Working Groups that are real problems in various research projects, such as the research project between CERN Research Institute and Chulalongkorn University and Suranaree University of Technology, infrastructure and workforce development projects related to the Antarctic Neutrino Observatory. Therefore, the outcome and impact that will occur will take a long time, beyond the 1 year period of the project duration. For example, Ms. Warisara Charuchinda, while studying for a bachelor's degree participated in the GSI summer student camp in 2019 and do research about proton therapy for cancer. After that, she visited the radiation therapy facility at Chulalongkorn Hospital in January 2020 to learn about the use of protons to treat cancer. Later in 2021, while studying for a master's degree, she joined a joint research project between Chulalongkorn University and the Heavy Ion Research Institute and started a research on the use of computer simulations to compare the distribution of radiation doses produced by scanning an ion beam with and without a three-dimensional range modulator (COMPARISON OF DOSE DISTRIBUTION USING SCANNING ION BEAM WITH AND WITHOUT 3D RANGE-MODULATOR) to treat cancer or tumors in areas that move with breathing, such as lung cancer and liver cancer, and travel to GSI/FAIR to do research with real equipment with Dr. Ulrich Weber, a researcher in the Biophysics Department GSI. /FAIR in 2022 etc. and that's when we start to see the outcome and possibly impact of the project to send students to participate in the summer student program.

Future plan:

PSIT Foundation together with academic partners including the Synchrotron Light Research Institute (Public Organization), National Science and Technology Development Agency, National Astronomical Research Institute (Public Organization), and Chiang Mai University will carry out the following activities:

(1) Activities to select representatives of Thailand to participate in the summer student program organized by the research institute by selecting students and science teachers. Participate in 6 summer camp activities to raise awareness about high energy physics and inspire the new generation of youth to become important forces in Thailand's frontiers of research.

(2) Activities to disseminate knowledge and basic particle physics training: To prepare for basic particle physics to high school students and science teacher. The training "Thailand School on High-Energy and Astro-Physics" will be organized to prepare students for high energy physics and to study or do research at a high level and create an atmosphere of cooperation between institutions in Thailand.

(3) Inspirational activities: Representatives from Thailand attending those programs will be asked to share their experiences of doing research abroad, the life/career path of a researcher, etc. by publishing on social media such as TikTok, Instagram, Facebook.

Summer Camp Program and Activities	statistics of participants			plan for 3 years		
	start year - current year	number of batches	number of Participants (Person)	2023 (Person)	2024 (Person)	2025 (Person)
1. CERN High School Teacher Program and CERN International Teacher Week Program at Switzerland	2553 – 2565	12 batches	24	2	2	2
2. CERN High School Visit Programme at Switzerland	2556 - 2565	9 batches	123	-	18	18
3. CERN Summer Student Program at Switzerland	2553 - 2565	13 batches	37	4	4	4
4. DESY Summer Student Program at Germany	2546 - 2565	19 batches	49	4	4	4
5. GSI/FAIR Summer Student Program at Germany	2560 - 2565	4 batches	8	2	2	2
6. IceCube Summer Student Program at USA	2565	2 batches	2	2	2	2
total	243 person			14	32	32
	243 person			78 person		
7. Activities to disseminate knowledge and inspire - Training such as particle physics, astrophysics - Transfer experiences/inspire to the public through “Science camps for children and youth”, social media (e.g. TikTok)				-	300 person	300 person

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนางานวิจัย ขั้นแนวหน้า (Space Technology, Quantum Technology, High Energy Physics, Plasma)

Designing and Building a Payload for the Liquid Crystal Experiment on the International Space Station

Nopphadon Seniwong na Ayutthaya[a], Jutarat Kaewthong[a], Tanawut Rittidetch[a], Wuttipan Satienpaisan[a], Pemika Hirankittiwong[b], Natthawat Hongkarnjanakul[c], Sittiporn channumsin[c], Apichart Pattanaporkratana[a], Nattaporn Chattham[a,*]
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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 65%

Abstract:
The phenomenon known as Lehmann Rotation, induced by the transportation of gas through Freely Suspended liquid crystal films (FSLCFs) made of chiral molecules, has been observed in the form of line defects or 2π-wall rotations. At its essence, the 2π-wall represents a remarkable state where the liquid crystal director field completes a full 2π rotation around a closed loop, yielding an array of distinctive optical properties, notably birefringence and optical vortices. Here, we present a ground-based study of the dynamics of 2π-wall rotation under ethanol and water vapour concentration gradients above and below the FSLCFs. The payload to test this phenomenon on the International Space Station (ISS) has been designed and built to fit on the KERMIT (Keyence BZ-X800) microscope on the ISS. We are now preparing for the System Requirement Review (SRR) for the preliminary safety test of this payload to be launched to the ISS.

Rationales/Problem statements:
Currently, the development of space technology is considered another significant step in technology that many countries have continuously developed for a long time. Thailand itself has been involved in the development of this technology for over a decade, particularly in developing and using satellite technology. In addition to satellite development, many countries have also made advancements in other deep technologies by utilizing laboratories on the International Space Station (ISS). This is a high-level progress to extend technology on Earth beyond its current state. This research project is the first in Thailand to integrate knowledge from physics, chemistry, and engineering to create a payload for experimenting with Liquid Crystals in space, aiming to develop a technology for Liquid Crystal Display (LCD) that surpasses the current standards. In terms of revenue, the global LCD market size was valued at around USD 142.36 billion in 2022 and is projected to reach USD 231.75 billion, by 2030. With this market size, the higher standard of LCD to be develop under microgravity would benefit the industry in the long run for the future earth and space applications of this technology.

Objectives:
Our goal is to study the molecular-level mechanisms of the Lehmann Rotation phenomenon in liquid crystals due to concentration gradient of surrounding gas and temperature variations. In this study we aim to develop a payloads according to safety requirements in space for thin liquid crystal film preparation devices for the experiment on the International Space Station (ISS). The plan is to enhance the use of liquid crystals in creating efficient display technology and smart glass both on earth and in space. This research project would also benefit the country in terms of increasing the number of researchers and engineers in

the fields of liquid crystals and space science and space engineering in Thailand.

Progress/Findings/Results:

The study revolves around thin membranes composed of smectic liquid crystal films placed under the influence of microgravity. These membranes have garnered significant attention as a result of the intriguing Lehmann Rotation phenomenon, a response to the flow of gas through FSLCFs constructed from chiral molecules. The manifestation of Lehmann Rotation presents itself as line defect or 2π-wall rotations. At the core of this phenomenon, the 2π-wall signifies a remarkable state where the orientation field of the liquid crystal undergoes a complete 2π rotation along a closed loop. In this context, we introduce a ground-based exploration into the dynamics of 2π-wall rotations under varying ethanol concentration gradients, both above and below the FSLCFs. Our goal is to draw comparisons between the behaviors of 2π-walls and their correlation with the Lehmann effects under both terrestrial and microgravity conditions by using image processing to assist in observing the behavior and changes in the 2π-wall defects. MATLAB and Python are primary programs used for analysis of the data in our experiment. We successfully developed the defect tracking program using MATLAB and film thickness measurement with Python. Several physical parameters can be extracted from the experiment to prove the project's science concept. The payload for this experiment is also under development along with proving the science concept.

Conclusion:

Payload for liquid crystal film proving Lehmann rotation experiment can be constructed under the heat gradient and gas flux passing through thin liquid crystal film. The defect tracking and film thickness measurement programs has been successfully developed to gather experimental data from the payload.

Current Output:

1.The prototype of the payload has advanced to 65% completion, positioning us well for entry into the first NASA Safety Review.

2. https://doi.org/10.1016/j.molliq.2023.123535, Journal of Molecular Liquids (Q1, IF 6.63)

Challenges/Problems and Possible solutions:

Since this is Thailand's first project participating in an experiment on the International Space Station (ISS) with NASA, we are not familiar with the documents, regulations, and space laws required for launching the payload to the ISS. NASA has recommended that the research team hires a US payload developer from the NASA REMIS Program as a consultant to coordinate all safety reviews and prepare the necessary documents for the team.

Future plan:

Our payload is scheduled to undergo the 1st NASA safety review (System Requirement Review, SRR) by the end of this funding year.

Equatorial Plasma Bubble Study and Effects on Advanced Technology

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 66%

Abstract:

ในช่วง 24 เดือนที่ผ่านมา คณะผู้วิจัยได้ดำเนินการวิจัยดังต่อไปนี้: (1) การศึกษาและการพัฒนาการทำนายการเกิดพลาสมาบับเบิ้ลและพารามิเตอร์ไอโอโนสเฟียร์โดยอาศัยเทคโนโลยีปัญญาประดิษฐ์ (2) การพัฒนาแบบจำลองดัชนี K สำหรับประเทศไทย (3) การวิเคราะห์ผลกระทบและการเปลี่ยนแปลงของความถี่วิกฤติในชั้น E (foE) และ Sporadic-E (foEs) ในบริเวณ EIA (4) การลดผลกระทบของพลาสมาบับเบิ้ลที่มีต่อความแม่นยำในการระบุตำแหน่งโดยอาศัยการแปลงเว็บเลตเหนือภูมิภาคเอเชียตะวันออกเฉียงใต้ (5) การพัฒนาแบบจำลองค่าแก้ไขสำหรับความผิดพลาดที่เกิดจากชั้นบรรยากาศไอโอโนสเฟียร์สำหรับเทคโนโลยี PPP-RTK และพัฒนาแบบจำลองทำนายค่าประวิงเวลาชั้นไอโอโนสเฟียร์

Rationales/Problem statements:

พลาสมาบับเบิ้ลเส้นศูนย์สูตร (Equatorial Plasma Bubble: EPB) คือปรากฏการณ์ซึ่งบริเวณด้านล่างของชั้นไอโอโนสเฟียร์ (ชั้น F2) ประมาณ 250-400 กิโลเมตรจากพื้นดิน มีความไม่เสถียรของปริมาณอิเล็กตรอนสุทธิจะส่งผลต่อคุณภาพของระบบสื่อสารและระบบการนำร่อง (Navigation) ของอากาศยานและการระบุตำแหน่งแม่นยำสูง (Precise Positioning) สัญญาณวิทยุหรือสัญญาณดาวเทียมที่ส่งผ่านชั้นบรรยากาศไอโอโนสเฟียร์ พลาสมาบับเบิ้ลจะเกิดขึ้นในบริเวณเส้นศูนย์สูตรและเขตละติจูดต่ำ แต่นักวิจัยยังขาดความเข้าใจอย่างชัดเจนปัจจัยที่ส่งผลต่อการเกิดพลาสมาบับเบิ้ลรายวันหรือเรียลไทม์ ทำให้ยากต่อการทำนายสถิติการเกิดรายวันและเรียลไทม์ งานวิจัยที่เกี่ยวข้องกับ GBAS, PPP-RTK การสังเกตการณ์เปลี่ยนแปลงของ foE และ foEs ที่เกิดขึ้น ลดผลกระทบของภัยคุกคามด้วยการเฝ้าระวังจากสถานี VHF Radar และระบบดาวเทียมนำทางสากลหลายระบบ

Objectives:

1. เพื่อศึกษาและวิเคราะห์การเกิดซินทิเลชันและสถิติการกำเนิดพลาสมาบับเบิ้ลโดยใช้เซนเซอร์หลายชนิด
2. เพื่อพัฒนาการทำนายการเกิดพลาสมาบับเบิ้ลและพารามิเตอร์ไอโอโนสเฟียร์โดยอาศัยเทคโนโลยีปัญญาประดิษฐ์ รวมทั้งพัฒนาแบบจำลองดัชนี K สำหรับประเทศไทย
3. เพื่อวิเคราะห์ผลกระทบและการเปลี่ยนแปลงของความถี่วิกฤติในชั้น **E (foE)** และ **Sporadic-E (foEs)** ในบริเวณ **EIA** ณ เอเชียตะวันออกเฉียงใต้ และสร้างแบบจำลอง **foE** โดยอาศัยโครงข่ายประสาทเทียม
4. เพื่อนำเสนอวิธีการใหม่ที่ใช้ลดผลกระทบของพลาสมาบับเบิ้ลด้วยข้อมูล **VHF Radar** และระบบจีเอ็น เอสเอส
5. เพื่อพัฒนาแบบจำลองค่าแก้ไขสำหรับความผิดพลาดที่เกิดจากชั้นบรรยากาศไอโอโนสเฟียร์สำหรับเทคโนโลยี **PPP-RTK** และพัฒนาแบบจำลองทำนายค่าประวิงเวลาชั้นไอโอโนสเฟียร์

Progress/Findings/Results:

คณะผู้วิจัยได้พัฒนาาแบบจำลองการคาดการณ์ ESF แบบจำลองคาดการณ์ ESF ดำเนินการโดยใช้ข้อมูลอนุกรมเวลาในเดือนวิษุวัต ซึ่งครอบคลุมระหว่างปี 2008 ถึง 2019 ด้วยเทคนิค โครงข่ายประสาทเทียม (Artificial Neural Network: ANN) และ หน่วยความจำระยะยาวระยะสั้น (Long-Short Term Memory: LSTM) นอกจากนี้ได้ทำการคำนวณการกระจายของดัชนี K เทียบกับดัชนี Kp ตลอดทั้งวันโดยข้อมูลตั้งแต่ปี ค.ศ. 2014 ถึง ค.ศ 2019 การคำนวณดัชนี K ในพื้นที่ด้วยสนามแม่เหล็กโลกที่วัดได้จากสถานีภูเก็ต (เส้นศูนย์สูตรแม่เหล็ก) ในส่วนการดำเนินการเก็บผล foE และ

foEs รวมถึงค่า foE ที่ทำนายจากแบบจำลอง IRI-2016 จากสถานีทั้ง 3 แห่ง แห่ง (เชียงใหม่ ชุมพร โคโตตาบัง) ในช่วงปี ค.ศ. 2010-2018 ได้ทำเสร็จสิ้นจะมีการวิเคราะห์ต่อไป

ผลกระทบของพลาสมาบับเบิ้ลที่มีต่อการระบุพิกัดโดยอาศัยค่าดัชนี S_4 ของระบบดาวเทียม GPS ในระหว่างวันที่ 10 - 14 เดือนพฤษภาคม พ.ศ. 2564 จากสถานีเครื่องรับ GPS จำนวน 3 สถานี ได้แก่ สถานี CUSV (ประเทศไทย), สถานี HKWS (ประเทศจีน) และสถานี THKK (ประเทศพม่า) แสดงให้เห็นว่าค่า SNR และดัชนี S_4 มีความสัมพันธ์กันแบบผกผัน และท้ายที่สุดได้มีการศึกษาการแก้ไขค่าไอโอโนสเฟียร์ในระบบการระบุตำแหน่งแม่นยำสูง พบว่าในพื้นที่ใกล้เส้นศูนย์สูตรแม่เหล็กและพื้นที่ละติจูดต่ำจะมีความแปรปรวนในชั้นไอโอโนสเฟียร์สูง ซึ่งส่งผลต่อประสิทธิภาพการระบุตำแหน่งโดยเฉพาะการระบุตำแหน่งแม่นยำสูง ดังนั้นในรายงานความก้าวหน้านี้จะแสดงความแปรปรวนที่เกิดจากชั้นไอโอโนสเฟียร์โดยใช้แผนที่ชนิด 2-D และแผนที่ Keogram

Conclusion:

ผู้วิจัยได้พัฒนาแบบจำลองการคาดการณ์ ESF โดยใช้แบบจำลอง ANN และ LSTM แบบจำลอง LSTM ที่เสนอสามารถให้ประสิทธิภาพที่ดีสำหรับการพัฒนาแบบจำลองการคาดการณ์ ESF แบบจำลอง LSTM ที่นำเสนอทำงานได้อย่างมีประสิทธิภาพในการลดการประเมินค่าที่สูงเกินไปเมื่อเทียบกับแบบจำลอง ANN ในการคำนวณดัชนี K ท้องถิ่น พบว่า EEJ ในเวลากลางวันลดประสิทธิภาพของการคำนวณดัชนี K เมื่อตั้งค่า L9 ต่ำหรือสูงเกินไป การวิเคราะห์การกระจายของดัชนี K ท้องถิ่นของภูเก็ตและดัชนี Kp สามารถควบคุมผลกระทบ EEJ ได้ในการคำนวณดัชนี K ท้องถิ่นหากตั้งค่า L9 อย่างเหมาะสม ในส่วนค่า **foE** ในช่วงปี ค.ศ. 2010-2018 ผลที่ได้พบว่าค่า foEs ที่ปรากฏในตอนกลางวันมากกว่าตอนกลางคืนสำหรับสถานีเชียงใหม่และชุมพร อย่างไรก็ตาม foEs ปรากฏในช่วงกลางคืนมากกว่ากลางวันสำหรับสถานีโกโตตาบัง นอกจากนี้ foEs มีความถี่เฉลี่ยสูงสุดสำหรับสถานีชุมพร ขณะที่สถานีโกโตตาบังมีความถี่เฉลี่ยต่ำสุดเมื่อทำการเปรียบเทียบผลในปีเดียวกันสำหรับสถานีทั้ง 3 แห่ง

ในส่วนการลดผลกระทบจาก EPB พบว่าวิธีการ Quadratic Best Fit มีความเหมาะสมต่อการทำนายค่า SNR ที่ได้จากค่า ROTI ที่ปรับแก้ได้เมื่อมีซินทิเลชันระดับต่ำเกิดขึ้น ในขณะที่ วิธีการ Linear Best Fit มีความเหมาะสมต่อการทำนายค่า SNR ที่ได้จากค่า ROTI ที่ปรับแก้ได้เมื่อมีซินทิเลชันระดับปานกลางและรุนแรงเกิดขึ้น ท้ายที่สุดในการสร้างแผนที่ชนิด 2-D และแผนที่ Keogram ได้นำผลการทดลองเปรียบเทียบกับเครื่องมือวัดชนิดแม่นยำสูงเรดาห์ VHF ซึ่งติดตั้งอยู่ที่พระจอมเกล้าฯลาดกระบังวิทยาเขตชุมพรพบว่าสามารถใช้บ่งบอกความผิดปกติได้

Current Output:

Publication: 11 journals

Challenges/Problems and Possible solutions: ไม่มี

Future plan:

1. วิเคราะห์การเกิดพลาสมาบับเบิ้ลโดยใช้ข้อมูลจาก VHF radar และ แผนที่ TEC
2. พัฒนาแบบจำลองสถิติการเกิดสเปรดเอฟด้วยเทคนิค B-spline
3. ระบุภัยคุกคามที่มีต่อการนำทางอุปกรณ์ UAV
4. ปรับปรุงประสิทธิภาพของระบบ PPP-RTK ด้วยค่าประวิงเวลาชั้นไอโอโนสเฟียร์จากประเทศไทย

Investigating beyond the Standard Model physics in collaboration with CERN

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Project duration: 1 year, from 01/04/2023 to 31/03/2024
Current progress: 60 %

Abstracts:

In this project, we are concentrating on both the theoretical and experimental aspects of high-energy particle physics. On the theoretical front, our focus lies in exploring new physics beyond the Standard Model and interpreting the results obtained from the Large Hadron Collider (LHC). In the realm of experimental high-energy physics, we actively engage in two LHC experiments: ALICE (A Large Ion Collider Experiment) and CMS (Compact Muon Solenoid). Within the ALICE project, besides conducting physics analyses using data from the experiment, we also endeavor to enhance the knowledge and skills of our staff in the realm of pixel sensors, with potential applications in the field of medicine. Within the CMS experiment, our primary emphasis is on analyzing data to hunt for rare processes predicted by the Standard Model and explore the possibilities of new physics.

Rationales/Problem statements:

Our project is rooted in the dynamic field of high-energy particle physics, encompassing both theoretical and experimental dimensions. Its underlying rationale is driven by the imperative to elucidate fundamental inquiries regarding the universe's fundamental makeup and behavior. On the theoretical front, we focus on two core objectives: probing novel physics beyond the confines of the Standard Model and deciphering the ramifications of data derived from the Large Hadron Collider (LHC).

In the sphere of experimental high-energy physics, we actively engage in two LHC experiments: ALICE (A Large Ion Collider Experiment) and CMS (Compact Muon Solenoid). Within the ALICE project, we not only analyze collected data but also cultivate advanced skills and knowledge related to pixel sensors. This holds the potential for applications in the medical field, augmenting the scope of our research.

Meanwhile, within the CMS experiment, our primary aim is to conduct exhaustive analyses

to unearth rare processes anticipated by the Standard Model and explore new frontiers in physics. This project is driven by the aspiration to contribute meaningfully to our understanding of the universe's fundamental mechanisms through high-energy particle physics research.

Objectives:

1. To characterize sensor of bent silicon sensors using particle beams.
2. To develop applications of machine learning techniques with CMS data at the LHC.
3. To study high energy particle and cosmological theories.
4. To expand research connections between Thai and foreign universities, research institutes and CERN, and to develop the person-power in high energy physics.

Progress/Findings/Results:

In this research proposal, we have achieved the following milestones:

- We have successfully published three papers in prestigious T1/Q1 journals, focusing on theoretical and phenomenological physics. These publications encompass two contributions in the field of cosmology and one in phenomenology. The latter serves to interpret the 3-sigma signals obtained from the CMS experiment.
- Progress has been made in the realm of sensor characterization, employing pixel sensors derived from the ALICE experiment. Our test station, situated at SLRI, has facilitated this endeavor. Furthermore, we are actively engaged in the enhancement of sensor design for an updated pixel sensor version. Additionally, we are exploring its application in the medical field, particularly in the context of proton CT at Chulalongkorn Memorial Hospital.

Conclusion:

In summary, our ongoing research efforts have yielded promising results, including the successful publication of three papers in prestigious journals spanning theoretical and phenomenological physics. Additionally, we've made significant strides in sensor characterization using pixel sensors from the ALICE experiment, with further advancements in sensor design and its potential application in medical settings. Our work continues to contribute meaningfully to these fields, and we look forward to further developments and discoveries in the future.

Current Output:

3 publications include (1) Eur. Phys. J. C 83, 421 (2023), (2) Eur. Phys. J. C 83, 657 (2023), and (3) PLB 845 (2023) 138129

Challenges/Problems and Possible solutions:

A delay in the availability of the radiation source and damage to the test sensor prompted researchers to take action. They will transport the damaged sensor to Thai Microelectronics (TMEC) for the creation of a new test sensor and commence measurement of certain properties while awaiting the radiation source.

Future plan:

The high-energy physics program will maintain its current trajectory, with a dual focus on theoretical and experimental aspects. On the theoretical front, our endeavors will encompass collider physics, including investigations beyond the standard model, as well as cosmology. In terms of experimentation, our commitment lies in the continuous analysis of LHC data, particularly from Run-3, along with ongoing efforts in detector development and application, and the enhancement of our computing infrastructure. Our outreach initiatives will be closely coordinated with CERN, featuring events such as the Flavour Physics and CP Violation Conference scheduled for May 27-31, 2024, at Chulalongkorn University, and the Asia-Europe-Pacific School of High Energy Physics taking place between June 12-25, 2024, in Nakhon Pathom. Additionally, we are actively developing further outreach programs to commemorate CERN's 70th anniversary.

Postdoctoral Researchers for Beyond the Standard Model Research

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 60%

Abstract:
This joint research project aims to foster collaboration between established and emerging researchers from Thai universities to advance our understanding of physics beyond the Standard Models and modern cosmology while bolstering Thailand's High Energy Physics and Plasma infrastructure. The theoretical and phenomenological aspects focus on constructing and exploring new models for cosmological inflation, dark matter, and dark energy within particle physics. Postdoctoral researchers will contribute their expertise and guide Thai students in these theoretical pursuits, encompassing topics such as neutrino mass models, quantum information, black hole thermodynamics, and non-extensive thermodynamics of black holes. Concurrently, the project concentrates on constructing a free-electron laser at Chiang Mai University, with a specific focus on generating super-radiant THz Free-electron Lasers. This collaborative effort, supported by two decades of collaboration with CERN, aspires to position Thailand as a leader in high-energy physics in Southeast Asia and within the global high-energy physics community.

Rationales/Problem statements:
Recent advances in theoretical and phenomenological high-energy physics, including the discovery of the Higgs boson and cosmological revelations, have deepened our understanding of the Universe. However, fundamental questions persist: the role of supersymmetry, the nature of inflation, dark energy, dark matter, and the relationship between scales in particle physics, gravitation, and cosmology. The search for new physics beyond the Standard Model continues, necessitating future collider experiments. Additionally, mysteries in the strong nuclear force persist, especially at lower energies.
In the realm of accelerator science, Chiang Mai University's PBP-CMU Linac Laboratory (PCELL) is pioneering the generation of ultrashort electron and photon pulses, offering new avenues in life and materials sciences. The establishment of an infrared free-electron laser (IRFEL) facility, equipped with advanced accelerator systems, promises groundbreaking research opportunities in Thailand and Southeast Asia, spanning THz radiation, MIR radiation, X-rays, and advanced experimental stations.

Objectives:
1. To increase the person-power in the frontier science, especially in high energy physics
2. To create the world-class working environment in science
3. To strengthen the domestic research network on high energy physics

4. To study beyond standard model physics from the neutrino
5. To study thermodynamics of black holes
6. To develop the production of THz free-electron laser from electron beam produced by linear accelerator at Chiang Mai University

Progress/Findings/Results:

Progress in Establishing a Super-radiant THz FEL Beamline at Chiang Mai University: The design of the magnet undulator is complete, with some components identified as misshapen and requiring reconstruction. The salvageable parts have been integrated to form a shorter undulator. Initial measurements of the magnetic field have been conducted. Simultaneously, we have undertaken a simulation study of electron motion within the undulator's magnetic field and the resulting radiation using WAVE software.

Progress in theoretical high energy physics: Cosmological model from non-extensive properties of black hole, Quantum information and black hole thermodynamics and Exploring S3 Modular Symmetry with Type-I seesaw. All three projects are conducted in schedule.

Conclusion:

In summary, our progress includes the completion of the magnet undulator design and the integration of salvageable components for a shorter undulator in the Super-radiant THz FEL Beamline at Chiang Mai University, along with initial magnetic field measurements and ongoing electron motion simulations. In theoretical high-energy physics, our projects, including a cosmological model based on non-extensive properties of black holes, investigations into quantum information and black hole thermodynamics, and the exploration of S3 Modular Symmetry with Type-I seesaw, are all on schedule, marking significant advancements in our research.

Current Output:

Publication is in progress.

Challenges/Problems and Possible solutions:

For accelerator project, some pieces are mis-shaped. The work needs to be redone.

For theoretical project, mathematical models are not easy to solve, work is in progress.

Future plan:

1. Complete the study and provide outputs as promised in the proposal
2. Present in the national and international conferences

HEPCT: High-Energy Frontiers, Dark Matter, Neutrino

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 55%

Abstract:

This research project aims to enhance collaboration and research capabilities among physics institutions in Thailand under the High Energy Physics Consortium and other institutions at the international level. Through the cooperation of the JUNO and KATRIN Collaborations, the outcomes encompass not only the development of human resources for active engagement in frontier research but also the transfer of technology from large-scale experiments, leading to the establishment and utilization of laboratory facilities and product prototypes.

Rationales/Problem statements:

Neutrino research is at the forefront of high-energy physics research. Several large-scale experiments have been proposed and built to measure the properties of neutrinos. These experiments require advanced technology for enhanced signal precision, necessitating international collaboration due to the substantial investment involved. Thai educational institutions presently contribute to the JUNO and KATRIN Collaborations, offering a strategic shortcut for leveraging global research challenges. This approach enables Thailand to develop its workforce and high-tech innovation ecosystem significantly, achieving remarkable progress with a modest budget and maximizing value.

Objectives:

JUNO

• To construct a dark laboratory for studying the impact of magnetic field on the performance of PMT.

• To investigate the impact of the rebars on the residual magnetic field around CD-PMT and VETO-PMT.

• To develop SNiPER for simulating interactions of light with PMT, and compare the results with experimental test.

• To develop methods for detecting neutrino signals from the co-annihilation of dark matter particles within the solar core.

KATRIN

• To design and prototype a mobile magnetic field sensor

• To develop Kassiopeia for computing magnetic field inside the spectrometer

• To design the magnetic and electric field configurations inside the spectrometer

Progress/Findings/Results:

• Our research team has successfully constructed a dark laboratory, which includes the construction of EMF shielding coils to neutralize the Earth's magnetic field. The laboratory

has been used for the magnetic field sensor chip measurement test to measure the magnetic field. These sensor chips will be used to develop a mobile magnetic sensor for the KATRIN experiment.

• Our research team found that, despite the increase in magnetic fields in the regions where CD-PMT and VETO-PMT are installed due to the effects of the rebars, it still remained within the acceptable range specified by the JUNO experiment.

• Our research team has acquired knowledge of the GEANT4 simulation program to develop the SNiPER program for the JUNO experiment. We are successfully able to simulate the photon emitted from the photo-diode which later hits the PMT in the VETO region.

• Our research team has successfully developed a method for detecting neutrino signals from the co-annihilation of dark matter particles. The team has employed an optimized Machine Learning model for comparison with the Linear Regression method, utilizing parameters from the PMT pulse shape to perform pulse shape discrimination.

• Our research team has studied and gained an understanding of the components of a mobile magnetic field sensor for KATRIN experiment. We have examined the characteristics of sensor chips used for measuring magnetic fields and is in the process of developing a magnetic field probe set capable of measuring higher-intensity magnetic fields.

• Our research team has learned the Kassiopeia program and comprehended the effects of magnetic and electric fields on the motion of electrons in the KATRIN main spectrometer.

• Our research team has designed adjustments to the magnetic and electric fields in the main spectrometer for the TRISTAN project of the KATRIN experiment. This has resulted in reducing the percentage of electrons reflected back to the source from 1.0% to only 0.4%.

Conclusion:

Our research team has worked to strengthen academic collaboration and research initiatives among physics institutions in Thailand and the JUNO and KATRIN Collaborations. The research project has been successfully executed according to the established plan.

Current Output:

• A dark laboratory equipped with the Earth magnetic field shielding.

• A new method for detecting neutrino signals from the co-annihilation of dark matter particles for the JUNO experiment.

Challenges/Problems and Possible solutions: -

Future plan:

• study the PMT performance in relation to the impact direction of photoelectrons.

• simulate interactions of light with PMT by using SNiPER, and compare the results with experimental test.

• prototype a mobile magnetic field sensor

• further develop the Kassiopeia simulation program

Infrared and Terahertz Free-Electron Laser Facility for Strengthening Frontier Research Ecosystem in Thailand

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Project duration: 1.5 year, from 01 August 2022 to 31 January 2024 (6 months extension)

Current progress: 85%

Abstract:

In frontier science research, development in advanced and specialized instruments or techniques is important. Infrared free electron lasers (IR-FELs) are advanced light sources that have a wide range of applications across various scientific, medical, and industrial fields due to their unique characteristics such as tunability and high peak powers. The goal of this project is to develop a mid-infrared (MIR)/terahertz (THz) light source and experimental stations designed for high-field irradiation, spectroscopic and ultrafast interaction applications. The activities are divided into three categories. The first part is dedicated to construct the electron accelerator system and MIR/THz-FEL. The second part focuses on development of experimental stations including THz transition radiation (THz-TR) station, THz time-domain spectroscopy (THz-TDS) and electron irradiation station. The third part is to implement infrared spectroscopic techniques in the pilot experiments including ionic liquids (ILs), perovskites, and DNA/cells for solar cell, energy storage and cancer therapy applications, respectively.

Rationales/Problem statements:

The motive that has driven us to build an IR FEL facility is to provide scientific tools for supporting frontier researches in material science, soft-matter and solid-state physics, life science, etc. The radiation frequency tunability and high radiation field are the FEL's major advantages over conventional lasers employing atomic or molecular stimulated emission. Development of such IR FEL facility with advanced experimental stations requires experts, deep knowledge, and advanced technology in many aspects, *e.g.*, electron accelerator, beam physics, optics, computer control, mechanical and electrical engineering, etc. The IR/THz FEL facility developing at Chiang Mai University (CMU) will be the first facility of this kind that will provide the experimental stations for users in Thailand and Southeast Asia.

Objectives:

1. Develop the facility for MIR/THz FEL, coherent THz-TR and short-pulsed electron.
2. Develop experimental stations comprising of THz-FTIR spectroscopy, THz-TDS and short-pulsed electron irradiation station.
3. Apply MIR/THz spectroscopy to study ILs for energy storage device application.
4. Apply MIR/THz spectroscopy to study perovskite/metal oxides for solar cell application.
5. Study the effects of electron beam irradiation on DNA/cells

Progress/Findings/Results:

Design, construction and installation of components in the accelerator system and MIR-FEL beamline are almost completed. The construction and magnetic field measurement of the THz FEL undulator magnet are on-going. The characterization of electron produced from the RF gun was conducted. The new 3-phase HV transformer of the linac pulse forming

network (PFN) was installed and tested. The maximum linac RF power of ~7 MW was measured, assuring the ability to achieve 10-25 MeV electron beam. Design and order of optical components in the THz TDS system were conducted. The installation and commissioning are on-going. The design of setup for electron beam irradiation on DNAs/cells is conducted by using a beam dynamic simulation employing ASTRA code and Monte Carlo simulation utilizing GEANT4 toolkit. The studied parameters for electron beam irradiation emphasized on an electron energy range of 10-25 MeV, and a dose rate range of 0.01 - 1000 Gy/s. For pilot experiment studies, multilayered perovskite structures were investigated using FTIR spectroscopy. The study for using THz radiation to investigate the superconductivity dynamics of Josephson junction was conducted. This results in a proposed plan for the next fiscal years. The study of IL solutions was performed using FTIR spectroscopy and THz-TDS. The solvents of ILs ([Emim][NTf2] and [Ehim][NTf2] mixed with DMSO) were prepared for different mole fractions. This study enables the detection of changes within the molecules of the ionic liquid solvents, confirming vibration modes using a molecular model based on density functional theory (DFT).

Conclusion:

The facility for utilizing MIR/THz FEL, THz-TR and short-pulsed electron has been established at CMU. Experimental stations comprising of THz-FTIR spectroscopy, THz-TDS and short-pulsed electron irradiation station are developed. Pilot experiments to study ILs, perovskite/metal oxides, and effects of electron beam irradiation on DNA/cells using spectroscopic techniques are conducted.

Current Output:

- **Publications:** 1 paper in Scopus Q1 (Tier 1), 1 paper in Scopus Q2
- **Conference presentation:** 16 oral (10 inter., 4 national), 5 poster (1 inter., 4 national)
- **Prototype:** Quadrupole magnet, Dipole magnet, Steering magnet
- **Manpower Development:** 4 researchers, 12 Students (6 Ph.D., 4 Master, 2 Bachelor)
- **New process:** Study of ILs and perovskite thin films using THz-FTIR spectroscopy
- **Laboratory:** Electron linear accelerator and MIR/THz free-electron laser facility
- **Collaboration:** 8 (3 domestic, 5 international)

Challenges/Problems and Possible solutions:

Problem: The transformer of linac PFN was burnt due to ageing of more than 30 years. The failure of this part leads to the delay of linac and electron beam operation, which effects to the generation of THz-TR and MIR/THz FEL.

Solution: We modified the design and order new transformer from a local vender in Thailand. The construction takes several months because they never built such high-power transformer. The delivery of the transformer was in April 2023. Installation and test of the system were performed and it is current working as expected.

Future plan:

The electron beam optimization for THz-TR, MIR FEL and THz FEL will be performed when the operation of the linac RF system is stable. Then, the radiation production for these three radiation types will be proceeded.

Science and Technology of Measuring High Energy Particles and Plasma in Space

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Project duration: 1 year, from 01 April 2023 to 31 March 2024

Current progress: 50%

Abstract:

Space technology has been gaining significance in any nation's economy, communication, security, and other important aspects. We proposed this project to support the development of Thai space technology. We plan to design and fabricate Thailand's first particle detector in space to be attached onto a polar-orbit satellite. The PMU-B funding has allowed us to conduct frontier research in space science. We operate and maintain two neutron monitor stations in Thailand and Antarctica, while collaborate with and analyze data from neutron monitors worldwide. We lead the shipborne cosmic-ray detector mission scheduled to travel across many continents. We actively participate in studies using an extremely large cosmic-ray detector in China. We also develop theoretical models, perform computer simulations, and analyze data of plasmas to understand particle transport in space. The objective is to advance Thailand's space science and technology to an internationally competitive level.

Rationales/Problem statements:

Thai researchers have recognizable contributions to basic research in space science at global stage, but we have not successfully gathered our expertise to create tangible technology and are starting to lag behind even in the regional level. The Thai Space Consortium has been formed by many institutes to build Thailand's first satellite equipped with different payloads, one of which is our particle detector designed to perform novel scientific studies on space weather. As people travel by planes more frequently, health effects due to cosmic rays or solar energetic particles have become concerning. Satellite communications, national security, and future space exploration will benefit from scientific understanding of space weather. We investigate fundamental questions on the properties of high-energy cosmic rays such as spectral variation and anisotropy, plasmas and particle transport mechanisms, solar physics, and geophysics to learn about our local cosmic environment.

Objectives:

1. To design, model, and construct space-based particle detectors to study cosmic rays and issue space weather warnings.
2. To measure and analyze cosmic-ray data from ground-based detectors, mainly neutron monitors and a massive cosmic-ray project led by China.

3. To analyze data on magnetic turbulence in space and propose theoretical models describing particle transport mechanisms and processes which affect cosmic rays.

Progress/Findings/Results:

For the space detector development, we have improved our PIN diode silicon detector to introduce smaller leakage current. An experiment for NIM readout of electronic pulse heights and particle energy calibration was carried out using standard radiation sources and accelerators at various facilities. The electronic system for signal amplification has achieved considerable progress at reducing background noise while amplifying faint signals from the silicon detector. The performances of the scintillator and SiPM-based detectors designed by our team have been observed by operating at the Princess Sirindhorn Neutron Monitor (PSNM) in Chiang Mai, Thailand.

For ground-based cosmic-ray projects, we manage the PSNM to ensure its normal data collection. We analyze data and perform computer simulations to study the cosmic-ray flux and spectral variations. Recent findings with support from the PMU-B were shown at international conferences as 9 separate presentations, some of which will be further revised and submitted for additional journal publications. We also collaborate with the Large High Altitude Air Shower Observatory (LHAASO) in China to study very high-energy cosmic and gamma rays using combined air shower detectors. The principal investigator is part of the editorial board responsible for the quality control of all LHAASO publications. Other members of the Thai team have served as internal reviewers. Our main analysis with LHAASO was presented at the 38th International Cosmic Ray Conference (ICRC) in Japan on behalf of the collaboration. During the time period supported by PMU-B, 4 LHAASO manuscripts have been published or accepted for publication in Q1 journals. We are finalizing our analysis and preparing a draft manuscript for a Q1 journal publication.

On the magnetic turbulence and cosmic-ray transport study, we have presented our findings at the 38th ICRC and submitted 3 manuscripts for publication in Q1 journals. The first manuscript is on particle-in-cell simulations of shock formation in a plasma. The second involves collaborating with other research groups to analyze particle motions in strong magnetic fields with highly turbulent structures. For the third one, we have used public data from NASA's Parker Solar Probe to study the Alfvén waves near solar wind production sites.

Conclusion:

Various projects have proceeded as planned. We have built a working detector prototype which is being tested using available radiation sources. Many research topics yielded substantial outputs including 5 publications and 2 submissions in Q1 journals during this reporting period. Other studies with preliminary results have been presented at the top international conference in the field of cosmic rays. Some ongoing analyses in the pipeline with sufficient progress will soon be released. We will focus on delivering all the outputs as promised in the proposal for the rest of the funding term.

Current Output:

1. A working detector prototype
2. *Nucl. Inst. Meth. A*, 1056, 168622
3. *Phys. Rev. Lett.*, 131,151001
4. One accepted by *Astrophys. J. Suppl.* and one accepted by *Science Advances*
5. One submitted to *Phys. Plasmas* and two submitted to *Astrophys. J.*

Challenges/Problems and Possible solutions:

The second round of funding will be paid only after the final report submission, so we have no support for the second half of the grant. The progress report is also overly complicated.

Future plan:

We will improve the performance of the particle detector prototype and continue our effort at maintaining PSNM, collaborating with international research teams, and producing publications as promised with PMU-B. This project will train researchers and students to become valuable human resources for Thailand's space science and technology.

Study of the Fast Ions Behaviour in Neutral-Beam and Ion-Cyclotron-Range-of-Frequency-Wave Heated Fusion Plasma in Large Helical Device Using the Compact Neutron Emission Spectrometer

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 50%

Abstract:
In nuclear fusion devices, plasmas are primarily heated by the auxiliary heating systems, such as neutral beam (NB) injection and/or ion cyclotron range of frequency (ICRF) waves. These systems are the primary source of fast ions. Understanding fast-ion transport is one of the important issues to achieve high-performance plasmas and progressing toward a fusion power reactor. The Large Helical Device (LHD) is the world's largest stellarator/helical systems located in Gifu, Japan. For a deeper understanding of fast-ions behavior and the excitation mechanism of fast-ion-driven MHD in LHD, measurement of fast-ion energy distribution was initiated by compact neutron emission spectrometers (CNESs). Under the PMU-B grant, CNES based on a conventional liquid scintillation detector and a newly developed CLYC7 scintillation detector having tangential- and perpendicular-sightline were installed in LHD. Using the tangential-sightline CNESs, a significant Doppler shift effect of the D-D neutron energy due to the high-energy fast-ion injected by tangential N-NB is investigated. Using the perpendicular-sightline CNESs, the double-humped shape with the peaks corresponding to Larmor motion of P-NB deuteron are observed.

Rationales/Problem statements:
The work is proceeding according to the plan, and we have full confidence that it will be successfully completed within the project's scheduled timeline.

Objectives:
1. Enhance understanding of fast-ion slowing down process resulting from NB injections and ICRF wave heating in LHD through tangential and perpendicular CNESs.
2. Enhance understanding of fast-ion confinement in non-axisymmetric system and excitation mechanism of fast-ion-driven MHD instabilities.
3. Publish a minimum of four articles in high-impact international journals indexed in ISI/Scopus Q1.
4. Foster research expertise in plasma and fusion energy in Thailand by engaging at least nine researchers and/or students in this project.
5. Strengthen collaboration between Thai researchers and international experts in the field.

Progress/Findings/Results:
The LHD uses both tangential N-NB injections introducing fast ions at approximately 190 keV and perpendicular P-NB injections introducing fast ions at about 80 keV. To further comprehend the slowing down of fast ions and the underlying mechanism behind fast-ion-driven MHD instabilities, CNESs have been utilized. CNES incorporating both a conventional liquid (EJ-301) scintillation detector and the newly developed Cs_2LiYCl_6:Ce with a ^{7}Li-enrichment (CLYC7) scintillation detector have been operational in LHD since 2020. The EJ-301-based CNES has a capability in a wide neutron emission rate (S_n) region due to the fast decay time of its signal. For measuring D-D neutrons, the EJ-301 requires

data unfolding since it senses the recoiled protons generated from elastic collisions. On the other hand, the CLYC7 detects these neutrons through the $^{35}Cl(n,p)^{35}S$ reactions, thereby lessening the need for complete data unfolding. However, the CLYC7 generates signals with a relatively extended decay time, restricting its operation primarily to lower S_n regions.

In investigations employing tangential-sightline CNESs, a significant Doppler shift effect in D-D neutron energy was observed due to high-energy fast-ion injections by tangential N-NB. The upper and lower shifted neutron energies were detected when fast-ions circulated toward and away from the tangential CNES, respectively. However, no significant energy shift was observed from fast-ions injected by the perpendicular P-NB. Additionally, during the low S_n deuterium plasma discharge with P-NB injection, neutron energy spectra were measured using perpendicular-sightline CNESs. Both EJ-301-based and CLYC7-based CNESs identified a double-humped shape, corresponding to the Larmor motion of P-NB deuteron. Employing the five-dimensional orbit following code DELTA5D, the neutron energy spectra anticipated to be recorded by the CNES were calculated, factoring in the detector's energy resolution. The calculated D-D neutron energy spectrum closely aligned with experimental findings. Furthermore, the D-D neutron spectrometry was conducted in a high Sn ICRF wave-induced plasma overlaid on P-NB-heated deuterium plasma, using EJ-301-based CNES. Notably, peaks broadened due to ICRF wave heating.

Conclusion:

Under the PMU-B grant, the operation of CNES to enhance the understanding of fast-ion behaviors during NB and ICRF-heated plasmas in the LHD has been successful. This project significantly contributes to the development of expertise in plasma and fusion energy among researchers, young scholars, and students engaged in the program. Moreover, it serves as a platform for strengthening collaborative efforts between Thai researchers and international experts from Japan, China, and Korea.

Current Output:

2 published papers, 3 under review papers, and 5 preparing manuscripts.

Challenges and Possible solutions:

Thailand is well aware of the importance and necessity of plasma fusion technology and is enthusiastic about being part of this global experiment. This project is dedicated to accelerating our knowledge and developing human resources to align with international progress on plasma and fusion technology especially on neutron and fast ion diagnostics and energetic particle physics study.

Future plan:

We initiated the 'International Consortium on Fusion Plasma Technology' engaging in activities that span both domestic and international fusion devices. With the support of PMU-B, Thai researchers have been conducting experiments at the LHD using CNES. In 2024, our work will include using CNES in DIII-D in the USA. Additionally, projects involving imaging neutral particle analyzers (INPA) in LHD and stacked diamond detectors in EAST, China, are started. TINT has recently commenced operations of the Thailand-Tokamak 1 (TT-1). Our diagnostics in TT-1 will encompass a variety of tools, including the Heavy Ion Beam Probe (HIBP) and hard X-ray spectroscopy.

Raising Thailand's Fusion Technology toward International level through High Performance Neutron Detector

Nopporn Poolyarat[a*], Siriyaporn Sangaroon[b], Apiwat Wisitsorasak[c], Boonyarit Chatthong[d] , Ponkris Klaywittaphat[d] (Times New Roman, 12 points, full justification, * after the Principal Investigator)

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Project duration: 1 year, from 1/04/2023 to 30/03/2024

Current progress: 45 %

Abstract: Fusion will be a future source of clean and unlimited energy. Thailand is currently entering into fusion technology and international fusion community as from the development of the first tokamak, Thailand Tokamak-1. This project would strongly contribute to Thailand's ambitious fusion plan by collaboration with international fusion laboratory through high performance neutron detector.

Rationales/Problem statements: Controlled fusion reaction for energy production, D-T or D-D, often produces neutrons. To understand controlled fusion or the physics of plasma as a fusion source, one would need a good neutron detector. A stacked-diamond neutron detector is a novel compact neutron emission detector (CNES) that would help us to detect neutron better and get more insight of physical understand of plasma and fusion process.

Objectives: To develop high performance neutron detector for installation at international fusion device and develop international collaboration on fusion technology, especially on neutron measurement technology.

Progress/Findings/Results: Researchers have been onsite visited to EAST tokamak at Institute of Plasma Physics, Chinese Academy of Science (ASIPP), China and planed for a development of stacked-diamond neutron detector to install at EAST tokamak. This stacked-diamond neutron detector will increase the capability of neutron detection, from D-D or D-T fusion reaction, in addition to the current installed detector for more insight and understanding of plasma behavior and physics behind.

Conclusion: The stacked-diamond neutron detector has been designed and is currently under development. Once tested and calibrated, it will be installed at EAST tokamak for

Current Output: 1 Publication

Challenges/Problems and Possible solutions:

Future plan: Test and calibrate the stacked diamond detector, then install at EAST tokamak.

Enhancing Competency and Capacity of High-Level Manpower in Plasma Technology

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Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 40%

Abstract:
This project is a critical initiative aimed at nurturing and producing professionals with in-depth knowledge and expertise in plasma technology and fusion energy. It aligns with Thailand's human resource development policy to address shortages in specific sectors, adapting to the rapidly changing global landscape. The goal is to attract new students and researchers to join the diminishing group of plasma researchers in Thailand through its four research initiatives. The project's main deliverable is an increased number of new plasma researchers, evident from published works resulting from research funding. Some research outcomes also have potential for intellectual property protection and utilization. The ultimate objective of the project is to create a new generation of plasma researchers who will work in organizations/companies and contribute to advancing plasma research to a global standard, Thereby, Thailand's research in plasma is propelled to a level comparable to leading global institutions.

Rationales/Problem statements:
A limited number of high-quality researchers are found in Thailand compared to the demand, especially when contrasted with other countries. For example, Taiwan, South Korea, and Singapore boast 115, 101, and 79.5 researchers per 10,000 people, respectively. In contrast, Thailand is only equipped with 25 researchers per 10,000 people. Consequently, the aim of developing a new generation of researchers is pursued by this project, intending to enhance Thailand's presence among global leaders in cutting-edge technologies. The country's potential and expertise in plasma technology and other critical fields will be augmented. The plan places emphasis on researchers having their work published in international journals, anticipating advancements in team research, as reflected in h-index and citations. It is expected that this will lead to an elevation in the overall stature of Thai universities and the education sector.

Objectives:
1. To incubate a new generation of researchers with in-depth knowledge and capabilities in the fields of plasma technology and fusion energy.
2. Elevate research development in the field of plasma through collaboration with leading national and international organizations of plasma engineering.

Progress/Findings/Results:
Post-doctoral researchers are conducting four research projects as follows:

1. *Synergy of Inorganic Catalyst and Plasma-Assisted Catalytic CO_2 Conversion into Valuable Products*

To apply and fabricate prototype of plasma technology synergy with inorganic catalyst in catalysis of carbon dioxide conversion into valuable products.

2. *Plasma Catalytic CH_4 and CO_2 Conversion into Valuable Products over porous Ni/Al_2O_3 derived from MIL-53(Al) as Catalysts*

   To assess Ni-based catalysts on porous-Al_2O_3, specifically Al_2O_3 from MOFs i.e. MIL-53(Al), to improve microwave plasma-catalytic CO_2 and CH_4 conversion at mild conditions. The study seeks a deeper understanding of their role in these reactions, offering crucial insights for designing catalysts in the challenging plasma-catalytic process.

3. *Plasma-Based Technique and Related Disinfecting Techniques for Inactivation of Foodborne Pathogen and Residual*

   To propose a method to increase sterilization efficiency using PAW and supplementary technologies such as MNB, UV, and US, to enhance the effectiveness of disinfecting food and decrease residual in the food industry.

4. *Plasma-Enhanced Synthesis of Carbon Quantum Dots (CQDs) Materials*

   To study the synthesis of CQDs using the micro plasma technique which is a specific type of plasma with a small size and nonequilibrium features that are beneficial for CQDs and advanced nanomaterials synthesis. Furthermore, the agriculture wastes, the nanocellulose (NC-B) and carboxymethyl cellulose (CMC-B) from sugarcane bagasse have been used as carbon source for producing valuable CQDs materials.

Conclusion:

Post-doctoral researchers in this project are conducting four research projects that can contribute to advancing plasma research to a global standard, thereby propelling Thailand's research in plasma to a level comparable to leading global institutions.

Current Output:

- 4 Post-doctoral researchers

Challenges/Problems and Possible solutions:

Future plan:

1. Post-doctoral researchers are participating in international exchanges at the Korea Institute of Science and Technology (KAIST) in South Korea.
2. Analyzing experimental results and preparing final report.
3. Preparing research publications for international peer-reviewed journals at Tier 1 academic levels.

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านอุตสาหกรรมแห่งอนาคต (Future Industry – GHG Net Zero)

Manpower Development Program for National and International Greenhouse Gas Verification Systems to Meet Thailand's Net Zero Greenhouse Gas Emission Targets

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Project duration: 1.5 year, from 1 August 2022 to 31 March 2024
Current progress: 75%

Abstract:
The measurement and scrutiny of greenhouse gas emissions, along with the development of policies, plans, and exchange mechanisms, are imperative for steering a nation towards the goal of net-zero emissions. This transition is constrained by two key factors: the magnitude of greenhouse gas emissions to be managed and the timeframe within which action must be taken. The current policy trajectory of Thailand aims to achieve net-zero emissions by the year 2050, necessitating the management of approximately 500 million tons of greenhouse gases. Presently, the country has an audit workforce of about 80 individuals, with each auditor assuming responsibility for an annual greenhouse gas quantity of 0.4 million tons. To align with the established policy, an expansion of the auditing workforce to approximately 1250 individuals is imperative within the forthcoming 25 years. Urgent educational initiatives are required to equip these auditors with the necessary knowledge and skills. A systematic approach, inclusive of an environment conducive to sustained learning, is essential for cultivating a workforce capable of effectively managing greenhouse gas emissions in accordance with national policy.

Rationales/Problem statements:
The existing suite of carbon management courses, presently administered by various institutions, exhibits certain shortcomings. While numerous institutions are engaged in this educational endeavor, the content of the courses remains insufficient in addressing the contemporary demands of the field. Furthermore, a notable absence of continuity, coupled with a lack of case studies for practical application, has been identified. This academic analysis underscores the inadequacy of current curricula in covering essential knowledge pertinent to contemporary carbon management scenarios. Additionally, the absence of a structured continuum and the deficiency of case studies for hands-on training present considerable gaps in the educational framework. Moreover, the absence of accredited entities poses a challenge for individuals seeking employment post-education. This critique aims to delineate the lacunae within the existing educational framework for carbon management and proposes strategies for refinement, including the incorporation of case studies, establishment of accreditation bodies, and the augmentation of practical experiences.

Objectives:
The primary objective of this project is to formulate a curriculum that encompasses essential knowledge within a management framework conducive to sustainable and lifelong learning. The curriculum aims to provide a foundation that fosters sustainable learning experiences while ensuring adaptability throughout an individual's professional journey. The curriculum emphasizes a symbiotic relationship with industry practices, with practical segments drawn directly from operational environments. This strategy not only enhances the relevance of the educational content but also facilitates the development of a sustainable learning model. Furthermore, the initiative envisions the establishment of accrediting bodies to ensure an adequate number of accredited entities capable of accommodating the demand for skilled professionals.

Progress/Findings/Results:

This initiative has garnered collaboration from stakeholders in both the public and private sectors, with over 20 participating organizations contributing to the creation and oversight of a curriculum. The curriculum encompasses more than 10 subjects, covering fundamental knowledge in greenhouse gas management. Facilitated by this initiative, the curriculum has the potential to produce over 200 professionals in greenhouse gas management within a timeframe of 1.5 years.

Approximately 30 factories have engaged in this project as case studies, collectively representing the management of over 1 million tons of greenhouse gases. The training provided by this curriculum has the potential to yield cost savings exceeding 6 million Thai Baht, significantly reducing expenses while ensuring comparable outcomes. This training initiative has the potential to decrease workforce development time by over 40% and advocates for the accreditation of participating organizations. As a result, five organizations are anticipated to achieve accreditation, representing 50% growth in accredited entities compared to the original baseline.

Over 20 graduates and current students from this curriculum have secured positions with audit organizations and consulting firms. This signifies a successful integration of education and employment, emphasizing the practical applicability and demand for the skills acquired through this curriculum.

Conclusion:

This project cultivates a sustainable ecosystem for the development of a greenhouse gas management curriculum, aligning with the national goal of achieving net-zero emissions within the next 25 years. It signifies the establishment of a new standard in generating workforce capacity, synthesizing inputs from both public and private stakeholders. The initiative focuses on formulating, implementing, and overseeing a curriculum that responds to the escalating demand for expertise, thereby propelling the nation toward its net-zero aspirations. The curriculum, having been meticulously crafted and managed through collaborative efforts, is poised to become a valuable resource for individuals and organizations alike, facilitating broader community engagement.

Current Output:

Challenges/Problems and Possible solutions:

This imperative is rooted in the fact that the existing accredited entities is insufficient. Furthermore, the evolving nature of associated standards necessitates a proactive approach in augmenting the accreditation framework. By fostering a greater number of accredited entities, the curriculum stands to benefit from diverse inputs, resulting in a more robust and adaptable educational infrastructure. In tandem, the creation of professional networks in the form of associations is essential for providing ongoing guidance, supervision, and enhancements to the curriculum. This not only facilitates the dissemination of best practices but also ensures that the curriculum remains aligned with industry needs**.**

Future plan:

The creation of professional networks serves as a strategic approach to pooling expertise from both professional associations and accredited institutions. This collaboration is integral to the establishment of standardized curricula that align with the expectations of accreditation bodies. Simultaneously, these curricula are designed to cater to lifelong learning, ensuring their relevance and adaptability over an individual's professional trajectory.

Capacity Building on Nature-based Solutions for Carbon Net Zero

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Project duration: 1 year, from 24 April 2023 to 23 March 2024

Current progress: 83.33%

Abstract:

Mitigating greenhouse gas emissions following the NDCs goals is one of the urgent agendas to achieve. We now lack resources in terms of manpower to deal with such a situation. This project aims to build up high-performance researchers and people who can serve in an area of carbon credit job market through NbS platform for carbon net zero developed by this project which provides both training courses and a demonstration site for experience gaining. We have conducted some of the courses, and the first VVB and green carbon demonstration site are now under the document reviewing process. The blue carbon demonstration site and brain power are planned to be initiated in the second half of the year. We hope that our first-year outcomes and impacts could be useful for the next phase, and then can provide significant inputs to support national accomplishment in terms of net zero carbon policies and actions.

Rationales/Problem statements:

The carbon credit mechanism on NbS is important for climate mitigation due to high price from co-benefit and lower cost compared to technological developments. Moreover, in Thailand, high biodiversity in various natural ecosystems provides high carbon storage. One of Thailand's Long-term Greenhouse Gas Emission Development Strategies is achievement of CO2 removal of 120 MtCO2eq in 2037 (6 MtCO2eq/year). However, the number of NbS projects on T-VER was lower than other sectors. There were 55 carbon credit projects on NbS with 0.9 MtCO2eq/year. It was only 15% of the national target. It might be because lack of manpower and relevant knowledge. Currently, there are only 5 VVB and 25 VV. Therefore, this project aims to initiate capacity building (PD, VV, consultant, and high-performance researchers on NbS) and knowledge to drive CO2 reduction and removal to meet the country's goal of reaching carbon neutrality by 2050 and GHG net-zero emissions by 2065.

Objectives:

1. To initiate capacity building (PD, VV, consultant, and high-performance researchers on nature-based solutions) by collaborating with TGO, TISI, and the Council of Science Dean of Thailand Network.
2. To develop training modules for Nature-based solutions to be a national learning platform as Climate Change Academy/NbS Platform for Carbon Net Zero
3. To initiate new VVB for the country to maximize the learning and experience of manpower.

4. To set up the NbS demonstration sites for Thailand and Southeast Asia.
5. To set the baseline information that can be used to develop methods for carbon measurement for Thailand's various ecosystems.

Progress/Findings/Results:

From 3 main parts of the project: 1) VVBs and Brain Power, 2) Research and Knowledge, and 3) Eco-system. All components eventually aim to build and strengthen the capacity in the knowledge area of nature-based solutions for net zero carbon. In the initial phase, the Brain Power committee was appointed from 3 organizations (TGO, GISDA, and NbS project members) and promoted the project by the Council of Science Dean of Thailand, as well as the MOU agreement with the IUCN to provide academic support about the related issue of climate change. Next is the output from the course development in part of T-VER and VVB conducted by the TGO, and NbS courses (mandatory and optional), each course providing different levels of skills for learning. This will facilitate the capacity building process that can eventually feed the project's output as PD, VV, Consultant, and Brain Power to the job market that can support the goal of greenhouse gas mitigation. To establish and get the VVB registered, the process of related ISOs was studied, then the ISO 14065:2020 was done and submitted to the TISI to evaluate and certify the unit. In the section of demonstration sites representing 3 ecosystems, all to be used as the first demonstration site of each ecosystem in Thailand. The site for green carbon is now almost done with the registration to be the carbon credit project. The blue carbon site will be started later this year (done with the assessment in mangrove and seagrass areas) with the plan to complete it next year, then the teal carbon site will come up next. Then all demonstration sites can serve the role of site for experience cases under VVB and to be the area for carbon credit projects. Moreover, the project has published 2 international publications relating to the status and assessment of blue carbon in Thailand and Southeast Asia. We found that from our courses in the first phase, there are different groups of people interested in joining mainly from educational institutions, followed by private sectors, and some from government sectors. Participants have their own purposes for attending the courses, some of them aim to use knowledge and skills gained from our learning to help continue working in the field of conservation and carbon credit. From the project's early outputs, we can see the potential for continuing and improving on this aspect to help fill gaps in the country as well as the region.

Conclusion:

The project can deliver all the outputs committed in 6 months. Outputs delivered following 3 main parts of the project which can used to form the Climate Change Academy as the learning and experience platform that can serve for other purposes in the future. We can now answer 4 of all 5 objectives. The project can conduct all activities according to the timeline plan and deliver 100% of the outputs, 3 outcomes, and 1 impact on the academic aspect. In conclusion, we can complete activities according to the plan, and we are ready to continue working on the next steps.

Current Output:

1. Form the Brain Power committee from 3 organizations and public relations activity
2. Internal personnel training by PSUVVB (8 courses)
3. Training on preparing ISO 14065:2020 document by PSUVVB, document is now under review by TISI.
4. Area assessment of demonstration sites or coastal ecosystem (mangrove and seagrass)
5. Develop training models for PD, VV, consultant, and high-performance researchers on nature-based solutions, and conducted 4 training courses.
6. Publication (2 international publications)

Challenges/Problems and Possible solutions:

NbS is a concept that is rather new and there might have a lot of misunderstanding. Thus a good outreach, PR and strong capacity building should be able to overcome this challenge.

Future plan:

The remaining activities that will be completed for the first-year project are 1) continue the remaining NbS courses, 2) start the process of initiating the blue carbon demonstration site at Libong Island, Trang Province, 3) survey and collect the necessary database for the teal carbon demonstration site at Bueng Khong Long, Bueng Kan Province, 4) register the PSUVVB, and 5) Application process and conducting the brain power research. All of these can be used to enhance the continued efficiency of the project in the second year. We also open a platform for those who would like to consult and develop a project to combat climate change through NbS Concept as well as try to promote our work as well as work with all stakeholders.

Optimization and Utilization CO_2 for Integrated Methanol and Power Generation

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Project duration: 1 year, 1 April 2023 to 31March 2024

Current progress: 60 %

Abstract: "Optimization and Utilization of CO_2 for Integrated Methanol Production and Power Generation." The project is divided in three sections: The first is to minimize all waste after refinery by returning and combining with biogas mixed CO_2 as a raw material. The CH_4/CO_2 (30/70, 50/50 and 70/30 %v/v) with methanol solution (0, 10, 20, 30 and 40%) were tested and resulted that higher CH_4 ratio yielding higher rate of methanol. The second is using off gas (CH_4, CO_2, CO and H_2) from the previous process in electricity by a Stirling engine. The last CO_2 from electricity generation via an absorption process using an amine solution. The Aspen Plus software is used to adapt the existing equipment to suit the design values. Currently, the prototype set is being assembled and will be tested then separated CO_2 gas will be analyzed. The economic value is compared with CO_2 separation by PSA.

Rationales/Problem statements: Commercial methanol is a process which generates CO_2, but Biomethanol is a process that CO_2 utilization. The biomethanol production process involves the generation of waste biomethanol after refinery and residual synthesis gas composed of $CO/CO_2/H_2$, which contained heating value and can be used as a fuel for the overall bio-methanol production process. However, the selection of technology and process design is crucial and need to align with various parameters of the process and utilization strategies. Although, the utilization of $CO/CO_2/H_2$ gases released from the bio-methanol production process by using the Stirling engine for electricity production of sub-project 2. In order to reduce gas waste and respond to net zero waste policies. But the Stirling engine also emits CO_2 gas into the environment. Therefore, separating CO_2 gas from the Stirling engine's waste gas by amine absorption process is a strategy of this third sub-project for reaching the Net zero waste plan.

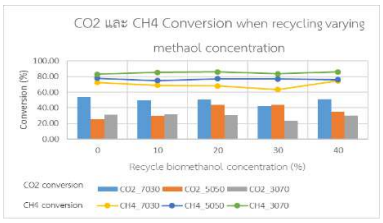
Objectives:

1. To promote the biomethanol from CO_2, by the recycling of residual biomethanol from refinery. Additionally, the discarded fuel gas will be used to generate electricity
2. To enhance a carbon dioxide capture system using amine absorption, this aims to reutilize carbon dioxide as a starting material in the biomethanol production.
3. To apply the research for the benefit of industrial sector that release CO_2 gas.
4. To develop and create personnel of applying research findings to industries, presenting research outcomes, or playing a significant role internationally in relation to CO_2.

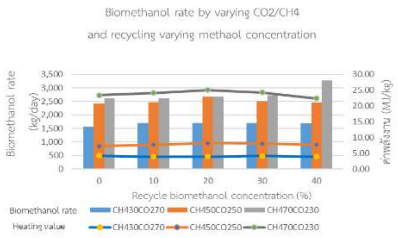
Progress/Findings/Results:

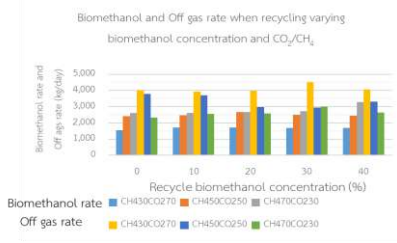
Methanol:

Currently, the first is to minimize all waste after refinery by returning and combining with biogas mixed CO_2 as a raw material. The CH_4/CO_2 (30/70, 50/50 and 70/30 %v/v) with methanol solution (0, 10, 20, 30 and 40%) were tested and resulted that higher CH_4 ratio yielding higher rate of methanol. Biomethanol waste after refinery by returning and combining with biogas mixed CO_2 as a raw material. The result showed CH_4 ratio effected to rate of methanol production off gas composition. Biomethanol is about 95 to 99% contained water less than 40,000 ppm, ethanol 2,500 ppm and acetone 1,000 ppm. The off gas has heating value about 5 to 20 MJ/kg depending on the ratio of CH_4 in the raw feed.



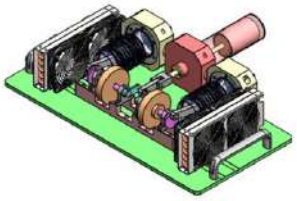
Gas out	CH_4	CO_2	CO	H_2	N_2
CH_4/CO_2	%	%	%	%	%
30/70	5.05	52.69	24.39	8.97	8.90
50/50	15.85	43.71	13.35	18.54	8.41
70/30	26.04	19.40	8.74	48.07	0.13

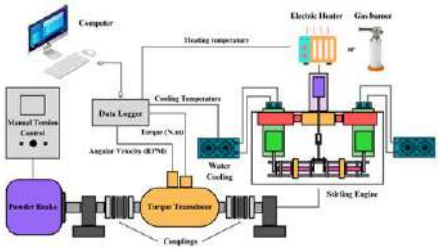




Stirling Engine:

During the first 6 months of operation, the research team has newly designed the Stirling engine, drawing upon fundamental knowledge in engine design, machinery component design, engine assembly techniques, material selection, and appropriate manufacturing processes. Consultation from project advisors has been instrumental in refining the design. The design phase is considered complete.





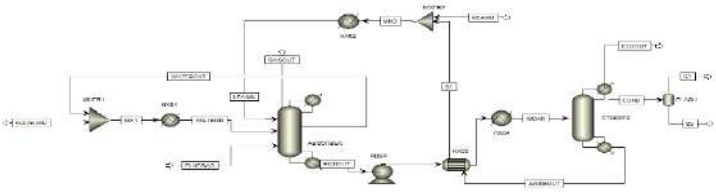
Stirling engine 3D design, current construction and working diagram of the system,

The CO_2 absorption process with amine solution was designed using Aspen Plus version 9, resulting in the dimensions of the equipment important in the process. Therefore, it was used

to improve existing equipment. According to the values designed from the Aspen Plus program.

Amine adsorption:

During this time, experiments were conducted to study the amine flow rate variables. and gas flow rate compare results with MEA and DEA absorbent substances and are still being studied. However, the operation has been delayed. This is because equipment such as cool boxes and exchangers must withstand the corrosion of amines. Therefore, it must be made to order specifically because it is small for a trial set. And some small control devices require time to transport goods from overseas. As a result, the assembly of the experimental excavation was delayed. However, the research team will expedite the study as soon as the prototype trial kit is completed. In order to get the test results and the research results to be in accordance with the next operational plan schedule.



Conclusion: Currently, the first is the recycling of biomethanol waste with CH_4 ratio effected to rate of methanol production and off gas composition reflecting to variation heating value about 5 to 20 MJ/kg. Biomethanol is about 95 to 99% contaminated with small amount of water, ethanol and acetone. The second subproject, has been fabricating components and selecting suitable materials and equipment for assembling the Stirling engine. The third subproject, has been assembling the prototype trial kit. which when assembled will be used to study various variables. that affect the separation of CO_2 gas and are used to calculate economic variables further.

Current Output: 3 Prototypes which are

1. A prototype of Biomethanol production from biogas combined with carbon dioxide and methanol at various concentrations. (under TISTR licensing)
2. Gamma-type Stirling engine prototype. (under construction)
3. Amine-CO_2 absorption experimental prototype. (under construction)

Challenges/Problems and Possible solutions:

1.The biomethanol has been operated along week effected to exhausted of researchers.

2.The design process is time-consuming due to the high precision required for the equipment.

3.Various components must be created and procured to be suitable, including testing their actual usability, resulting in a lengthy operation. To facilitate rapid refinement and development until it can be put into operation as quickly as possible.

4.The amine process was affected by financial problems with Silpakorn University procedures caused a delay in some of the equipment must be ordered from oversea. Time consuming is affected to the prototype trial kit to be delayed.

Future plan:

1. Following the scope of project.
2. Finalizing the construction of the Stirling engine and testing the operation and measuring

various parameters using testing equipment.
3. Study of various factors that influence on the separation of CO_2 gas with amines solution and tests with gas from the Stirling engine of sub-project 2 and returns the separated CO_2 gas to sub-project 1.
4.The economic values and CO_2 consumption are calculated and compared.
5. An academic article will be submitted to an international publication at the Quartile 1 or Tier 1 level and a complete research report.

Development of Advanced Nanomaterials for the Capture, Storage, and Utilization of Carbon Dioxide

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Project duration: 2 years, from 1 April 2023 to 31 March 2025

Current progress: 40%

Abstract:

Thailand is currently striving to mitigate the greenhouse effect by exploring ways to reduce carbon dioxide (CO_2) emissions. One approach involves the development of advanced nanomaterials, utilizing waste materials from the sugar industry such as bagasse and sugarcane leaves for trapping and storage. Additionally, CO_2 carriers are being created using the nanobubble technique to enhance the growth of economic crops. The transformation of CO_2 into carbon nanomaterials is also being pursued for energy storage materials. This research is focused on the development of nanomaterials with specialized functions for capturing, delivering, and converting CO_2, emphasizing low production costs, environmental friendliness, and practical application.

Rationales/Problem statements:

Global warming has emerged as a significant issue affecting countries worldwide, primarily due to the escalating levels of greenhouse gases in the atmosphere. The major contributor to this predicament is the heightened production of carbon dioxide (CO_2) resulting from the combustion of fossil for energy and emissions from various industrial plants. Guidelines for reducing CO_2 include its capture and storage, as well as its transformation into alternative forms. CO_2 capture and storage play a pivotal role in mitigating its impact. This research focuses on the development of advanced nanomaterials for CO_2 capture, storage, and utilization. The project is organized as **(**1) the development of nanomaterials for capturing and storing CO_2, **(**2) computer simulation studies of CO_2 capture and storage in materials, **(**3**)** the creation of CO_2 carriers using the nanobubble technique to enhance the growth of economic crops, and **(**4) the conversion of CO_2 into carbon nanomaterials for use in energy devices.

Objectives:

This project aims to the development of advanced nanomaterials for applications in the capture, storage, and utilization of CO_2.

Progress/Findings/Results:

The results of this study are summarized as follows.

- Activated carbon from sugarcane shells, treated at a temperature of 800 °C, demonstrated the highest efficiency in absorbing carbon dioxide gas. This activated carbon was able to absorb 173.61 milligrams of carbon dioxide per gram of sorbent.

Additionally, the project explored the carbon dioxide adsorption capacity of activated carbon derived from composite materials of natural rubber and highly porous activated carbon.

- Quantum calculation methods were conducted on the 2D nanomaterial structure with CO_2 adsorption on the surface of MoS_2, ZnO, ZnS, and nanocarbon ribbons. The study involved determining the placement of CO_2 molecules on the surfaces of these materials, aiming to calculate the most stable location for carbon dioxide adsorption.
- CO_2 nanobubbles (CO_2 NBs) with surfactant functionalization were generated. The modification of CO_2 NBs with surfactants results in smaller particles and better stability. The optimum ratio of the Span60:Tween mixture is 1.5:0.5 for CO_2 NB preparation due to the small particle size and good stability. Simulations of the CO_2 NBs system in aqueous solutions with varying Span60 concentrations revealed that an excessive amount of Span60 led to a decrease in CO_2 NBs stability.
- Powder particles of MgO, $CaCO_3$, and activated carbon were synthesized through grinding or ball milling, and then mixed in various ratios to create templates. The resulting mixture was combined with Mg metal in different weight ratios. The composite materials were subjected to heating in a tube furnace within the temperature range of 700 to 1100 ºC, releasing CO_2 gas into the tube at varying rates.

Conclusion:

(1) Activated carbon derived from bagasse and sugarcane leaves was been successfully synthesized to enhance CO_2 trapping efficiency.

(2) The CO_2 adsorption capacity of highly porous natural rubber–activated carbon composite material was developed to establish optimal conditions for capturing/storing CO_2 in the air.

(3) The absorption properties of CO_2 on various surfaces including MoS_2, ZnO, and ZnS have been investigated using quantum calculation methods.

(4) The functionalizations of CO_2 NBs with the Span60 and Tween20 mixture were prepared and the optimum ratio of the Span60:Tween mixture is 1.5:0.5 for CO_2 NBs due to the small size and good stability.

Current Output:

1 knowledge, 1 publication (Q1), 1 prototype, 1 oral presentation, and 1 MOA

Challenges/Problems and Possible solutions:

Many operational challenges stem from commonly used analytical tools or equipment in experiments, such as XRD machines and DLS machines. Delays often occur due to the need to wait for equipment and chemicals to prepare a sample. To address these issues, a proactive approach involves careful experiment planning that considers equipment availability. This includes organizing the work order and adjusting methods to be flexible while staying aligned with the main objectives, ensuring smoother operations.

Future plan:

1. Conducted experiments to evaluate the efficiency of activated carbon in capturing and storing CO_2, and analyzed experimental results
2. Calculated and analyzed data to understand the most stable adsorption locations.
3. Conducted experiments to study the impact of nanobubbles on enhancing rice growth
4. Analyzed the properties and characteristics of the produced carbon nanomaterials.

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ด้าน Global League and Research Institutions Re-Inventing

Enhancement of Thai Researcher Leaderships in Global Research Consortium in Low-Latitude Space Weather and GNSS Technology

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Project duration: 3 years, from 1/11/2021 to 31/10/2024

Current progress: 66%

Abstracts: During the last 6 months, we have made the following contributions: (1) Research on equatorial plasma bubbles and effects on aviation and (2) Active participation in international organization and committee (ISWI - COSPAR, IADC, UNOOSA, IAGA, AOSWA, IRI, URSI) and (3) Lead funded international research project

Rationales/Problem statements:

Awareness of Space Weather and its impact on modern technology has been growing and receiving wide attention from the government and academia all over the world. The global-level geomagnetic storm and local factors can cause local ionospheric irregularities such as equatorial plasma bubbles, which originate near the equator and move to higher latitude regions. Since this is an active area of research collaborations, there is a strong need to work together among various universities and institutes, to participate more in International-level projects which require collaboration among different countries, particularly, in equatorial or low-latitude regions, and to play a more important role at the regional or global level.

Objectives:

1) To elevate Thai researchers to be leaders in the world's important partners in space technology and GNSS technology in the low latitude region
2) To conduct international research on space technology and low-latitude GNSS technology
3) To create a database of space conditions and GNSS technology in low latitudes in Thailand (TEC index) that is standardized and can be used for reference

Progress/Findings/Results:

A. Research Part

1. Analyzed the EPB effects on GNSS systems

(a) Investigate nowcasting and forecasting techniques for the EPB models
(c) Analyze and compare the statistics of the EPB probability and durations at different latitudinal locations.

2. Implemented the two-dimensional ground facility error model for GBAS operations

(a) Propose two-dimensional ground facility error model from B-value in GBAS.
(b) Simulate a ground facility error model at Suvarnabhumi International Airport, Thailand.

3. Investigated the local DFMC SBAS corrections with the HOI delay mitigation in Thailand

(a) Generate the local DFMC SBAS corrections.
(b) Evaluate the preliminary accuracy of the local DFMC SBAS corrections with the HOI delay mitigation in Thailand.

B. Consortia/Organization Part

1. Organization Consortia Participation

(a) Appointed as Country Representatives to ISWI Meeting (Pornchai, Sittiporn), UNOOSA (Sittiporn)
(b) Attended meetings of ISWI, UNOOSA (Sittiporn)
(c) Appointed as Executive member of IAGA from 2023 to 2027 (Pornchai)
(d) Committee meeting of the IRI committee (Pornchai)
(e) Apply for Associate committee of AOSWA (Noraset, Suwicha)
(f) Steering Organizing Committee (SOC) to AOSWA (Pornchai, Sittiporn, Lin, Punyawi)
(g) Session convener: URSI GASS (Pornchai), AOSWA (Pornchai, Stiiporn, Lin, Punyawi)

2. Conference attendance

IRI 2023 Workshop, AOGS 2023 Workshop, ION GNSS+ 2023, URSI GASS 2023, EPB Workshop 2023, AOSWA 2023 Workshop, ICONSpace 2023

3. International Project Leader Funding

We are able to secure a 2-year ASEAN IVO Project from 2023-2025 with a Thai researcher (Prof. Pornchai) as the Project Leader.

Conclusion:

(1) Research part

Implemented the research works: analysis of the EPB statistical characteristics at different latitudinal locations, two-dimensional ground facility error model for GBAS operations in Suvarnabhumi International Airport, Thailand, and evaluation of the local DFMC SBAS corrections with the HOI delay mitigation in Thailand.

(2) Consortia/Organization participation

We have joined 5 international organizations as country representatives, steering committee or committee as well as received international funded project

Current Output:

Journal Publication: 1 journal (Q1)
Survey report on international consortia: 1 report, 1 platform
Number of researchers who join international consortia: 3 persons
Number of consortia/organizations to join: 5 consortia/ organizations
Number of international funded projects: 1 research project from ASEAN IVO ($80,000)

Challenges/Problems and Possible solutions:

We realize that it is quite costly to attend international meetings on a regular basis covering registration fees, accommodation, and travel expenses. Annual or biannual meetings of many organizations such as URSI, ISWI, UNOOSA are typically organized in Europe or the US. Without financial support in the future, it will be difficult to carry out our plans.

Future plan:

1. Organize a panel session “International activity in GNSS and Space Weather - how Thailand can contribute and have a International leading role?" at Queen Sirikit National Convention Center (QSNCC), on October 26th at 9 am -12 pm. From October 25-27
2. IGS and proposing the GNSS stations in the regional APREF network footprint
3. Join or lead an Action Team at International Space Weather Initiative (ISWI)
4. Attend steering committee of AOSWA and Committee of AOSWA 2024 Worskhop
5. Join AOSWA as Associate Member (Dr. Suwicha, Dr. Noraset)
6. Revise the ‘draft’ platform content
7. Total electron content (TEC) generation software is requested for use from UNOOSA (40+ countries)

Promotion of Thai Researchers to Associate Members of International Multidisciplinary Network in Carbon Reduction Renewable Energy Technology Design and Development

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 55%

Abstract:

This project aims to promote and elevate Thai researchers to be leaders in important world partnerships. We have partnerships, consisting of 14 researchers from 7 Thai universities divided into 4 levels (L1-L4) as follows: L1: Steering Committees/ Advisory Boards, L2: Project Leaders, L3: Joint Research, L4: New Researchers. Outputs of the project in 6 months are the following:

1. Level 1 Researcher(s) plan to apply for IEEE Fellow certification, received certification as an IEEE Senior Member, and is an expert in the Open Charge Alliance.
2. Level 2 Researchers have received research grants from JST and Erasmus+, in the process of submitting to become an ICTP network.
3. Level 3 Researchers have become CIMPA members and IEEE Member.

We designed a platform to upgrade Thai researchers to be a leader in the world network (CaRe Platform) and published 9 research articles in Q1 international journals.

Rationales/Problem statements:

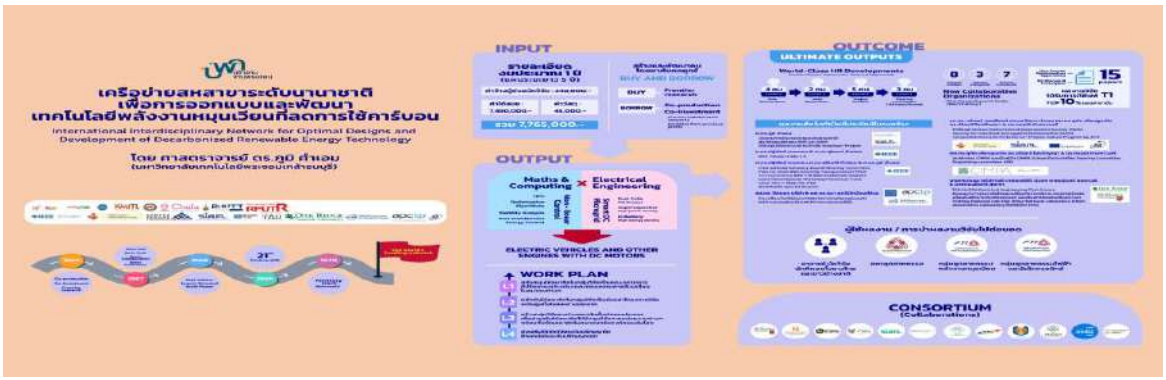
The goal in the strategic plan is to make Thailand an important production base for electric vehicles in the world. The research development and technology development related to electric vehicles is very necessary to use knowledge from many fields, electrical engineering, physics, or mathematics. On the other hand, researchers who produce research to support the electric vehicle industry and reduce carbon use are limited in numbers. Developing a model research workforce in Thailand is therefore very necessary. In particular, promoting Thailand to be a main leader in the world's important partners in the research. In order to exchange knowledge and develop joint research and strengthen collaboration including being a member of various international associations or organizations in order to expand the impact on the development of researchers and research in various fields related to the development of technology related to the use of renewable energy that will lead to reduction of carbon use in Thailand.

Objectives:

1. To raise the level of Thai researchers to be leaders in important world partnerships in the field of renewable energy for reducing carbon use and others.
2. To develop a platform for upgrading Thai researchers to be leader in the world network in technology for renewable energy to reduce carbon use and others.
3. To conduct international research on technology for Renewable energy for reducing carbon use.

Progress/Findings/Results:

This research project has used the strategy of expanding Networks to connect international associations or organizations with a Value Creation Model. The development of Thai personnel to become main leaders in important world partnerships, consisting of 14 researchers from 7 Thai universities divided into 4 levels (L1-L4) as follows: L1: Steering Committees/ Advisory Boards, L2: Project Leaders, L3: Joint Research, L4: New Researchers. The goals of L1 group members are encouraged to serve on international advisory/governance committees in various associations. L2 group members are encouraged to be leaders in high-level research projects both domestically and abroad. L3 group members are encouraged to become member of a research group between the country's leading institutions. For L4, to encourage researchers at the master's level to continue studies to the doctoral level and continue to do postdoctoral research upon graduation.



Picture 1: Overview of operations and goals of the research project

Activities:

1) Organize a meeting and workshop to exchange ideas and stimulate collaboration. Design and organize collaborative approaches between researchers in Thailand and abroad.
2) Create plans and activities, both short-term and long-term, between researchers and the international research-advisor network.
3) Organize activities according to the plan in cooperation with research networks both within the country and abroad including inviting network researchers for exchange research knowledge and attend international conferences.
4) Participate in short-term research studies.
5) Submit research to be published in international journals high-impact journals in Scopus/WoS Q1.
6) Extract lessons and summarize results for use in upgrading L1-L4 research groups.

The progress of this project 6 months are as follows:

1. Level 1 Researcher plan to apply for IEEE Fellow certification, received certification as an IEEE Senior Member, and become an expert in the Open Charge Alliance.

2. Level 2 Researchers have received research grants from JST and Erasmus+, in the process of submitting to the ICTP network.
3. Level 3 Researchers have become CIMPA members and IEEE Member.

From learning lessons and brainstorming, we designed a platform to upgrade Thai researchers to be leader in the world network (CaRe Platform)

Picture 2: CaRe Platform

A platform for elevating Thai researchers to become leaders in global networks in energy technology and basic research. This circulating driving design consists of the main factors which are the Global Network, BCG Economy and Brain Power. The internal factors of researchers that will lead to success are as follows:

- Role Model, which is an important part in promoting researchers. It will consist of inspiration and mindset relies on the 4P principles such as Publication, Patent, Product, Profit.

1) Leader Network Effect is the selection of leaders of the existing Network Effects.
   - Pushing members currently in the group up to a higher group.
   - Selection of people by designing appropriate activities
   - The selection of these individuals is found through their membership in various organizations.
2) Building Global Research COE is the selection of individuals for Leader Network Effect.
3) Global Visibility is showing ability to be evident to the outside.

Conclusions:

The progress of project 6 months are:

1. Level 1 Researcher plan to apply for IEEE Fellow certification, received certification as an IEEE Senior Member, and is an expert in the Open Charge Alliance.
2. Level 2 Researchers have received research grants from JST and Erasmus+, in the process of submitting to become an ICTP network.
3. Level 3 Researchers have become CIMPA members and IEEE Member.

We designed a platform to upgrade Thai researchers to be a leader in the world network (CaRe Platform) and published research article in international journals (Q1) 9 articles.

Current Output:

1. Thai researchers were elevated to become leaders in important global partnerships in renewable energy for reducing carbon use 10 persons.
2. Designed a platform to upgrade Thai researchers to be a leader in the world network (CaRe Platform) 1 platform.
3. Published 9 research articles in Q1 international journals.

Challenges/Problems and Possible solutions:

1. Budget disbursement for organizing activities is not flexible, clumsy and slow. There are many unnecessary steps in the process. As a result, in order for the operation to go according to plan, researchers have to reserve a large amount of money to organize activities by themselves first. This is very unpractical and imposing hardship on the already low-salary researchers. The reimbursement also takes considerably long time to be finalized, roughly two months after starting the reimbursement procedure.
2. The process of promoting researchers to become IEEE Fellows and receive funding from abroad may not be accomplished in a single year. Because the first year will

require a lot of talking, lobbying and planning together. Foreign applicants need to take time to submit and be considered for funding. Therefore, there is a need for continued action.

Future plan:

After 6 months, we have plan activities:

1. Being a conference/ International conference organizer.
2. Organize activities to extract lessons and summarize prototype results for use in upgrading L1-L4 research groups from approaches and activities that have been coordinated with research networks both within the country and abroad.
3. Presenting an operating model used to raise the L1-L4 research group based on approaches and activities in collaboration with research networks both within the country and abroad between 20 - 22 March 2024, under the theme “Renewable Energy for Sustainable SDGs” at Amari Pattaya Hotel, Chonburi Province.
4. Submit research to be published in international journals high-impact journals in Scopus/WoS Q1.

Development of Manpower in International Communities for Catalysis/Electrocatalysis for Zero CO_2 Emission (CZCE): Searching a New Pathway for the Net-Zero-CO_2 Emissions in Chemical Industry

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 80%

Abstract:

Herein, we are establishing the international communities for Catalysis/Electrocatalysis for Zero CO_2 Emission (CZCE) integrating several famous researchers in different countries including Thailand, France, The Netherlands, UK, Japan. Our team has focused on the development of catalysts/electrocatalysts for CO_2 reduction via two aspects: (i) suppression of CO_2 emission by replacing traditional processes with alternative technologies in chemical industries; (ii) converting CO_2 to high value-added chemicals/materials. Therefore, by both national and international collaboration, it allows us to establish many new technologies including the catalysts/electrocatalysts production derived from CO_2, demonstrating the CO_2 utilization to high value-added materials. Furthermore, we have successfully advanced the new technology of biorefinery to replace traditional processes using fossil resources to suppress CO_2 emission, such as the production of ethylene from bioethanol. In summary, we are integrating different perspectives for example frontier research and industrial research points of view together with the global citizen development.

Rationales/Problem statements:

As there is a massive amount of CO_2 emission from many sectors, particularly, in the industrial section, in this project we would like to establish an international consortium of Catalysis/Electrocatalysis for Zero CO_2 Emission (CZCE) containing eight Institutions: VISTEC, NSTDA, University of Bordeaux, Tu/e, Hokkaido University, Kyoto University, The University of Manchester, Thammasat University, in order to achieve two following main perspectives to reduce CO_2 emission: (i) suppression of CO_2 emission by replacing the traditional process with alternative technologies in chemical industries; (ii) converting CO_2 to high value-added chemicals/materials. Therefore, we expected that the outcomes from this project could sustainably initiate the research collaboration among different institutions from both inside and outside Thailand, especially for establishing a new sustainable technology of biorefinery together with CO_2 utilization.

Objectives:

1.To achieve near-zero CO_2 emission by replacing the traditional technologies in chemical industries by using alternative routes and simultaneous converting CO_2 and renewable biomass-derived compounds to high value-added chemicals

2.To further develop existing technologies originated from Thai researchers, for example, our technology for the catalyst production for worldwide catalytic/electrocatalytic applications via this collaborative project

3. To strengthen the research network and encourage as well as support young researchers

4. To increase the quality and the number of publications

5.To be the leader at the international level to be recognized in international societies

Progress/Findings/Results:

In this contribution, we divided the activities of this project into two main schemes: (i) to strengthen research activities via the development of frontier research/collaborative research according to the following two subprojects (Subproject 1: Development of heterogeneous catalysts and electrocatalysts for the production of high value-added chemicals and materials without CO_2 emission, Subproject 2: Development of heterogeneous catalysts and electrocatalysts for chemicals/biochemicals production from CO_2 under mild condition); (ii) to establish international network and society among various famous researchers regarding the development of catalysts and electrocatalysts with high efficiency for the production of fine-chemicals and materials with Net-Zero-CO_2 Emissions schemes.

For the first mission regarding the frontier research scheme, we have successfully developed several catalysts including different types of zeolite frameworks and porous metals that can be used as heterogeneous catalysts and electrocatalysts, respectively. In addition, we demonstrated the applications of these designer materials in a wide range of catalytic applications such as bioethanol to ethylene and carbon nanotubes (CNTs) with minimizing CO_2 emission and the direct conversion of CO_2 to high value-added materials. From these points, it allows us to be able to publish some parts of our research more than 10 publications. For the international networking activities, we further develop our own technologies which are present in more than 6 international conferences to illustrate that we have successfully transferred the knowledge of catalyst development from the scientific to pilot-plat point of view, for example. In addition, we strengthen the research network among several countries, including Thailand, Japan, France, the Netherlands, and the UK via several activities, for example, exchanging 5 Ph.D. students who are joining the joint or double degrees between VISTEC, and University of Bordeaux, and Eindhoven University of Technology. In addition, we have worked together under the research collaboration with Prof. Yonezawa Tetsu, Hokkaido University, Japan, Prof. Alexander Kuhn, University of Bordeaux, France, Prof. Emiel Hensen, Tu/e, the Netherlands, and Prof. Xiaolei Fan, University of Manchester, UK and this collaboration allows us to publish our 5 manuscripts in the international journals. In addition, we establish the new research network between VISTEC/NANOTEC and Institute of Atomic and Molecular Sciences, Taiwan by exchanging at least 4 students/researchers and organizing the Taiwan-Thailand symposium. Furthermore, we establish the new MOU agreement between VISTEC and University of Canterbury, New Zealand.

Conclusion:

We have successfully developed our project in both directions: (i) scientific research regarding the development of new technology for CO_2 utilization and biorefinery; (ii) establishing international network via several activities, including organizing international conferences/symposium/workshop, exchanging students/researchers among different institutions, successful producing our double Ph.D. degree candidates, and being recognition by international societies via international award, and being the member of editorial board.

Current Output:

- 9 publications in Q1 and 2 publications in Q2
- Organizing 1 International conference (NanoThailand2023)/1 international symposium (ChiraChem), 1 international workshop
- Being PI in the international grant (US Airforce), the member of editorial board (ChemPlusChem)/being recognition by Tremplin ASEAN award from the French academy of science and the French ministry of research and higher education (BILATERAL RESEARCH COOPERATION AWARD between French and ASEAN partners

Challenges/Problems and Possible solutions:-

Future plan:

- Further supporting young researchers to be able to be independently and finding further collaboration grant from both national and international funding agencies.

Promotion of Thai Researchers to Play an Important Role in Global Leading Partnership with the IceCube Neutrino Observatory for High-Energy Particles from Space

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 77%

Abstract:
Thailand, traditionally distant from polar research due to its tropical location, is now pioneering significant scientific initiatives in the polar regions, inspired by the vision of Her Royal Highness Princess Maha Chakri Sirindhorn. This project underscores Thailand's commitment to playing a pivotal role in an international collaboration with the IceCube Neutrino Observatory. The focus is on cutting-edge neutrino and cosmic ray research. This project involves the challenge of organizing trips to the South Pole, aimed at enhancing Thailand's expertise in science. The goal of this initiative is to make a significant contribution to worldwide scientific efforts, particularly in monitoring space weather, which may be linked to climate change, and in driving technological advancements.

Rationales/Problem statements:
The Royal Initiative Project of Her Royal Highness Princess Maha Chakri Sirindhorn is aimed at creating a leading global network by collaborating with the IceCube Neutrino Observatory in the field of high-energy particle physics, ranging from TeV to EeV levels.
The key reason why we need to collaborate with IceCube includes:

- Spatial Limitations: The detectors used must be large, covering an area of more than 1 km^2, and need to be buried 2-3 kilometers beneath the surface. These spatial limitations are a primary issue to build their own detectors.
- Budget Constraints: Constructing large-scale detectors requires an initial investment of over ten billion baht, along with an annual maintenance budget of at least one hundred million baht.
- Knowledge Limitations of Thai Researchers: Due to the vast and varied topics in cosmic rays and neutrino, it is necessary to integrate knowledge with the IceCube Collaboration, involving 14 countries and 58 institutions worldwide.

Objectives:

1. Develop young scientists through the IceCube Summer Student Program, including the development of educational and industrial manpower in Thailand.
2. Participate in IceCube's engineering teams through the Technical Working Group for the projects:
    a. IceCube Upgrade: Years 2023-2025
    b. IceCube GEN2: Years 2026-2030
3. Integrate research efforts to enable Thai researchers with expertise in theoretical, computer simulation, and data analysis to join the working groups of IceCube.

Progress/Findings/Results:
We succeeded in established two international cooperation networks, advanced engineering proficiency, elevated research standards, manpower development, leadership contribution,

Royal recognition, academic contribution, academic presentations, knowledge dissemination and additional achievements (please see details in current output session).

Conclusion:

Our progress has been succeeding following our plans (please see details in current output session).

Current Output:

The project has achieved remarkable results as summarized below:

1. Two International Cooperation Networks Established:
   - Chiang Mai University became a Full Member at SND@LHC CERN; Chulalongkorn University is an Associate Member.
   - Chiang Mai University strengthened its Associate Membership with IceCube, enhancing collaboration in research, technology, and education/outreach.
2. Enhanced Engineering Skills: Dr. Chana Sinsapwarodom attended a UW-Madison ice drilling workshop from July 30 to August 15, 2023.
3. Elevated Research Standards: A research team comprising Asst. Prof. Dr. Waraporn Nanthiyakul, Dr. Atchara Sereepianlert, and Dr. Wirin Sonsasethi was invited to participate in the IceCube event at WIPAC, USA.
4. Manpower Development: Doctoral students, including Ms. Yanee Tangjai, were sent to collaborate with the IceTop Tank research group at the University of Delaware (UDel), USA. UDel is a Full Member of the IceCube Collaboration, strengthening the research ties and fostering collaborative networks. Regular participation in the weekly cosmic ray working group was also facilitated.
5. Leadership Contribution: Project leader, Asst Prof. Dr. Waraporn Nuntiyakul, collaborated with US peers to co-author a White Paper and Proposal.
6. Royal Recognition: Received two audiences with Her Royal Highness Princess Maha Chakri Sirindhorn on 21 January and 27 May 2023.
7. Academic Contribution: Submitted a manuscript for publication in a Q1 quartile, ISI JCR-indexed journal in the field of astrophysics.
8. Academic Presentations: Showcased academic contributions both internationally (12 presentations) and nationally (5 presentations).
9. Knowledge Dissemination: Cultivated a learning ecosystem through workshops and utilized platforms like YouTube, TikTok, Facebook fan pages, and various websites to spread research group insights.
10. Additional Achievements: There were also accomplishments not explicitly mentioned in the Proposals Output/Outcome/Impact. For more details, refer to the appendix.

Challenges/Problems and Possible solutions:

Future plan:

- Publish IceCube research and create a framework.
- Expand the Thailand-IceCube Outreach project from a regional to an ASEAN-wide scope, highlighting Thailand's expertise in cosmic ray and neutrino research.
- Encourage ongoing visits by Thai engineers to the University of Wisconsin-Madison and the South Pole to acquire advanced engineering skills.
- Boost collaboration by expanding and strengthening both associate and full memberships.
- Promote understanding of how IceCube research is integrated and applied in space weather monitoring.

Uplifting Thai Researchers as Leaders in the Global Livestock Net-working

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Project duration: 1 year, from 1 April 2023 to 12 March 2023

Current progress: 70%

Abstract: This research project, in alignment with the country's BCG policy and UN SDGs, focuses on agriculture and food, aiming for in-depth research, cultivating a new generation of researchers, and building a robust network. Through this project study, it was found that adding microencapsulated LEMANGOS at 6% DM could notably improve the antimicrobial activity. This suggests that it could be used as a supplement to livestock to improve production efficiency and lower methane production and methanogen populations. The project has organized seminars, submitted four articles to international journals, and advancement researchers' careers path by securing appointments to Professor and Associate Professor positions. Five researchers have been nominated as the Animal Bioscience editorial members. Prof. Dr. Metha Wanapat was appointed as "Vice President of the World Association for Animal Production" (Vice President-Asia, World Association for Animal Production; WAAP 2023-2028). The plan is successfully executed, aligning with initial objectives.

Rationales/Problem statements: The global population is anticipated to rise by 38% to 9.6 billion by 2050, accompanied by an average lifespan increase of at least 9 years and significant age-specific demographic shifts. Recognizing this trajectory and the potential depletion of natural resources, proactive anticipation of changes in food, water, and energy resources becomes crucial. Particularly significant is the projected exponential increase in demand for animal protein sources, necessitating proactive management for future production efficiency and food security. This research specifically investigates the utilization of plant bioactive compounds as dietary supplements, aiming to replace antibiotics and influence the rumen fermentation process, microbiome diversity, methane reduction, and the production of nutrition-rich meat and milk. By targeting substances like conjugated linoleic acid (CLA), peptides, immunoglobulin, and lactoferrin, this study aims to contribute to the development of functional health foods.

Objectives:

- To promote the Thai-researchers as leaders among important global partners in the field of livestock production particularly in animal nutrition and feeding within the worldwide livestock industry.
- To develop and advance research in dietary supplements containing phytonutrients and to

facilitate the production of bioactive substances tailored for the livestock industry.

Progress/Findings/Results: Through this project study, it has been discovered that agricultural materials and fruit peel pellets, such as lemongrass and mangosteen peel, known as LEMANGOS pellets, underwent the microencapsulation technology process (microencapsulated LEMANGOS). This process preserves and protects biological substances within small particles. The study involved the fermentation process outside of animals (*in vitro* fermentation). The results demonstrated that supplementing microencapsulated LEMANGOS at levels ranging from 2 to 6% dry matter (DM) in roughage to concentrate (R:C) ratios of 40:60 and 20:80 enhances the efficiency of the rumen fermentation process. This supplementation reduces ammonia nitrogen concentration, decreases the population of methanogens, and consequently, lowers methane production. Therefore, it can be concluded that microencapsulated LEMANGOS at 6% DM exhibits the highest antimicrobial activity, surpassing the use of antibiotics such as Monensin. These findings suggest its potential use as a dietary supplement for livestock, aiming to enhance production efficiency. In addition, this project has organized special seminars and lectures. Furthermore, it has submitted four manuscript articles for publication in international journals, with one article stemming from the research study and three from literature reviews, all currently under review. Furthermore, researchers involved in the project have advanced the careers of personnel in science, research, and innovation. They have received a resolution from the University Council affirming their affiliation, thereby securing His Majesty the King's appointment to the position of Professor including 3 persons as well as one person holding the position of Associate Professor. Additionally, five researchers involved in the project and Prof. Dr. Metha Wanapat (project leader), were nominated to serve as editorial members of the journal Animal Bioscience. Moreover, Prof. Dr. Metha Wanapat was nominated to hold the position of “Vice President of the Association, World Animal Production” (Vice President-Asia, World Association for Animal Production; WAAP 2023-2028).

Conclusion: Based on this study, it could be concluded that Microencapsulated LEMANGOS demonstrates high potency and safety, making it a viable dietary supplement for livestock to enhance production efficiency. Encompassing other aspects of research work, the potential implementation of seaweed, agricultural biomass, and Omics technology in livestock feed industry are promising, and these advancements can have positive impact on food technology, nutrition, and functional foods, providing valuable information for the development of sustainable knowledge in the future. Moreover, the plan has been successfully executed in its outlined implementation plans, aligning seamlessly with the predetermined objectives.

Current Output:

- Four manuscript articles for publication (submitted and under review)
- Researchers have been elevated to 6 key persons (3-year duration) as follows:
    - Thai researchers who are committee members in the national livestock network, 2 positions (such as AHAT, ASANT, etc.)
    - Thai researchers who are committee members in 3 regional livestock networks (such as AAAP, AB, WBC, WAAP, etc.)
    - Thai researchers who are on the committee Advisor to working groups or subcommittees in international livestock network partners, 1 position (such as CGIAR, ILRI, ICARDA, FAO, LEAP, BRI, EU, etc.)
- One prototype product: lemongrass-mangosteen peel pellets (LEMANGOS pellet), which is an innovation for livestock.

Challenges/Problems and Possible solutions: -

Future plan: The project has been implementing as initially planned and progressively well without any problems. In fact, we have actually accelerated our project activities and have achieved the outputs successfully. During the next 6 months, we are intending to analyze the samples in the laboratory completely and hopefully to extrapolate the results and onward to prepare the manuscripts for publication, as well as inviting the foreign researchers to enrich the project activities and plan ahead for next year. Furthermore, more participation to present papers in International Conferences and joining in the invited missions as committee members will be implemented.

Upgrading the Safety Management System of the Synchrotron Light Research Institute to be Comparable to International Standards

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 50%

Abstract:
Synchrotron radiation source is the highest brilliant X-ray source comparing to other X-ray sources used in laboratories around the world. The intensity of the photon flux from synchrotron radiation source is more than a million times higher than X-ray tubes. Therefore, safety system and regulations for design and operation of the synchrotron radiation sources or particle accelerators are extremely vital. SLRI has been operating a synchrotron radiation source so-called the Siam Photon Source as a user facility for more than 20 years. In order to operate a radiation source such as particle accelerator, SLRI needs to strictly follow regulations on radiation safety controlled by a Thai nuclear authority (i.e. Office of Atomic for Peace). Since the opening of the facility, SLRI safety system has been well implemented until the radiation incident in 2021 and 2022 with some minor injuries. SLRI has therefore modified some regulations and developed a new system for better radiation protection.
In this project, two systems including personnel tracking system and safety dashboard have been developed. The tracking system is used to track the radiation workers in SLRI radiation area in real time using bluetooth technology. The system will send a signal to the accelerator control system when someone is present in the area. Another system, the safety dashboard using Grafana platform is used to broadcast some real-time information to radiation workers and public such as accelerator status, radiation level at beamlines and outside the accelerator building and PM2.5 at SLRI are shown. The project also organizes some activities to develop SLRI safety officers and staff's knowledges on safety and risk issues.

Rationales/Problem statements:
The safety system at SLRI for accelerator complex has been implemented for more than 20 years. Some sub-systems, therefore, need to be upgraded or replaced. Nowadays, new technologies are available in the market, the safety system for the synchrotron facility can be upgraded for higher efficiency and better performance. In order to improve our safety system and management to meet international standard level, our research team has chosen the synchrotron radiation facility in Taiwan; National Synchrotron Radiation Research Center (NSRRC) as a benchmark facility. NSRRC is a well-known organization in synchrotron community running two synchrotron radiation sources: Taiwan Light Source (TLS) and Taiwan Photon Source (TPS) with high output of more than 600 international academic papers and more than 2000 users per year. TLS has similar machine parameters to the SLRI synchrotron source while TPS has the same electron energy as the SLRI new machine.
After the fruitful discussion with NSRRC safety professionals, there are two aspects concerning for SLRI to approach: technology and people aspects. For technology aspect, a system to ensure the safety for radiation workers in the radiation area should be installed. In normal circumstance, before or during the electron injection process, no one is allowed to be present in this area. Such system can be used to ensure the safe situation. For the people

aspect, two activities including engagement and development should be performed. The problem of the people engagement comes from the lack of communication. To solve this problem, a dashboard will be created to show real-time safety information such as radiation level at beamlines and in the environment, PM2.5 outside the Siam Photon Laboratory or number of incident at the institute. This dashboard not only gives information related to safety, but also reflects the institute's transparency policy. This project is also going to develop the SLRI staff to gain more knowledge and experience on safety via lectures, trainings and facility visits.

Objectives:

- To improve the safety system and management at SLRI to meet international standard,
- To develop SLRI staff on safety for accelerator and beamline facility

Progress/Findings/Results:

- The prototype of the personnel tracking system is in progress. The system is based on Indoor Positioning System (IPS) using bluetooth technology. The procurement process has already been done. It is in the process of coding and creating the Graphic User Interface.
- Safety dashboard is in the trial process. It is developed based on Grafana platform. Some of the safety data such as radiation level and machine status come from radiation monitoring system and accelerator control system, respectively which means they are real-time data. PM2.5 and other climate parameters come from the weather station installed at SLRI.
- Human development, trainings and workshops related to safety aspects have been organized at SLRI.

Conclusion:

The project supported by PMU-B helps SLRI to improve the safety system and management. To improve the system into the right direction, the team considers NSRRC as a benchmark facility due to their performance and acceptance in the international level. To improve the safety system, two systems are being developed: a personnel tracking system and safety dashboard. The first system is used to track radiation workers when being present in the radiation area and record their location. The latter is used to show some important safety information such as radiation level at beamlines and outside the building, machine status and climate quality at SLRI. Apart from the system development, the team also organizes some activities including workshops and facility visits to develop people skills and knowledges.

Current Output: -

Challenges/Problems and Possible solutions:

Future plan:

The prototype of the personnel tracking system (1/4 of the radiation area) will be completed by the end of the project (1st phase). In the future, the system will be integrated to the safety access control and radiation monitoring system. This integration allows the system to estimate the radiation dose received by the individual. The personnel tracking system can be modified to use in other radiation area such as in hospital or radiation laboratory in university. The safety dashboard will be online for SLRI and public users.

Human resource development program will have to be continued for staff and users. Also, policy and regulation for safety aligned with the Thai laws will be updated.

Platform to Plasma and Fusion Technologies Development for Energy Sustainability

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Project duration: 1 year, from 1 April 2023 to 30 April 2024

Current progress: 35%

Abstract:

This project focuses on personnel development and establishing a collaborative research and development network. The Thailand Institute of Nuclear Technology (TINT) will concentrate on enhancing Tokamak machine expertise, leveraging the capabilities of personnel from both TINT and the Thailand Institute of Scientific and Technological Research (TISTR). TISTR contributes expertise in high-temperature-resistant materials, plasma torch, and plasma pyrolysis technology—imported production technology applicable to alternative fuels. Collaborating with TINT and the Center of Plasma and Nuclear Fusion Technology (CPaF) network, this project aims to use these technologies as educational tools, fostering machine and personnel capabilities. Ultimately, this collaboration aims to elevate both agencies to international standards, enhancing their overall capacities.

Rationales/Problem statements:

This platform poses challenges and encounters difficulties in collaborating with universities, agencies, private sectors, and research institutes both within the country and abroad. In response, we are committed to seeking and engaging with new universities and institutes to strengthen and broaden our collaborative network, fostering a more robust and effective platform for innovation and research.

Objectives:

1. Establishing a collaborative framework involving diverse research agencies and universities for the advancement of plasma and fusion technology through graduate studies and workforce development.
2. Exploring and evaluating innovative solutions ready for promotion, extension, or further development.
3. Expanding collaboration networks with government agencies, business entities, and the public sector within the country, across Asia, and beyond to enhance the collective impact."
4. Developing a comprehensive master plan, roadmap, and white papers based on the fundamentals of plasma and fusion technology. This initiative aims to contribute to policy-setting and advocate for achieving society-wide net-zero greenhouse gas emissions by 2050."

Progress/Findings/Results:

1. Training on the Tokamak TT1 device, Operation and maintenance for the main 4 system such us magnetic coil power supply, vacuum system, data acquisition system and diagnostic system.

2. Establishing a baseline operation for the TT1 device to facilitate future comparisons and experimental campaigns.
3. Conducting a comprehensive study and research exploration on plasma and fusion technology, specifically in Plasma Pyrolysis and Gasification, both nationally and internationally.
4. Cultivating cooperation by engaging in collaborative initiatives with research institutes within the country, with the intention of fostering expanded collaboration on an international scale. This collaboration involves the Thailand Institute of Nuclear Technology (Public Organization) and the Thailand Institute of Scientific and Technological Research.
5. Initiating brainstorming sessions to generate ideas and foster understanding with relevant agencies both domestically and internationally. These efforts aim to facilitate knowledge exchange and infrastructure sharing. Notable collaborations include Thai Union and MUANG SA AD CO., LTD.

Conclusion:

TINT's project focuses on advancing plasma and fusion technology through personnel development and collaborative research. TISTR's expertise in materials and technology complements TINT's mission to enhance Tokamak capabilities. Challenges in collaboration drive a commitment to engage new institutes for network strengthening. Objectives include creating a collaborative framework, exploring solutions, and advocating for net-zero emissions. Progress involves hands-on Tokamak TT1 training and expanding knowledge in Plasma Pyrolysis. Collaborations with Thai Union and Muang Sa AD Co., Ltd., highlight a commitment to knowledge exchange. In essence, the project makes strides in innovation, collaboration, and sustainability in plasma and fusion technology.

Current Output:

MOU: collaborating between Thailand Institute of Nuclear Technology (Public Organization) with Thailand Institute of Scientific and Technological Research.

Challenges/Problems and Possible solutions:

This platform encounters challenges in fostering collaboration with universities, government agencies, private sectors, and research institutes both within the country and abroad. Currently, there are partnerships with two private sectors: 1. Thai Union (Yes), and 2. MUANG SA AD CO., LTD. (Yes). While there is no existing collaboration with King Mongkut’s Institute of Technology Ladkrabang, there are established partnerships with research institutes, namely the Thailand Institute of Nuclear Technology (Public Organization) and Thailand Institute of Scientific and Technological Research (Yes). To address existing challenges, a proposed solution involves seeking new affiliations with universities and institutes to expand collaboration.

Future plan:

1. Investigate and analyze information pertaining to plasma and fusion technology both domestically and internationally.
2. Foster collaboration by engaging with local research institutes, with the aim of extending these partnerships to include international counterparts.
3. Facilitate idea generation and understanding through discussions with relevant agencies both nationally and internationally, promoting the exchange of knowledge and infrastructure sharing.
4. Host a forum dedicated to knowledge exchange, targeting both public and private research institutes within and outside the country.

5. Engage in an experimental study to comprehend the functioning of a plasma machine, with the objective of integrating findings into the fuel production process. Explore avenues for collaboration and enhancements to Thai machinery.
6. Participate in an experimental study to comprehend the operations of the Tokamak and analyze experimental outcomes. This endeavor aims to inform joint experimental planning and enhance the efficiency of the Tokamak TT1 machine.

Promoting the Science and Technology Services in Thailand

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 34%

Abstracts:

The project promoting the science and technology services in Thailand. The purposes of this study were include supporting public awareness, creating mechanisms for accessing science, research, and innovation services, and establishing tools for information retrieval. The project encompasses the following activities:

1. Study and Development of Smart Search System: Analysis and design of the Smart Search system to enhance awareness and accessibility to science and technology services. Utilization of data analytics technology for efficient data analysis, covering services from 12 government agencies and the National Science and Technology Information System (NSTIS) database. This system is designed to be efficient and capable of verifying search commands to deliver results that align with the users' needs to the greatest extent possible.

2. Awareness and Access Promotion Activities: 1. Training seminars to promote awareness and access to science, research, and innovation information. 2. Marketing activities to boost awareness and accessibility to science, research, and innovation services, including participation in national-level exhibitions.

3. The Press Tour activity is conducted to promote awareness and facilitate access to science, research, and innovation services.

Rationales/Problem statements:

The provision of services in the fields of science, technology, and innovation is not yet widespread. This is due to limited access for service recipients, including private sector entities, government agencies, and interested individuals. Access to information on science, technology, and innovation services is constrained, with decentralized databases across various organizations. Centralized databases of service information are often outdated.

Contacting some service-providing agencies may involve long waiting times, slow service processes, or lengthy queues. Services may be available only during specific periods without conflicting with educational activities, adhering to government office hours. Service-providing agencies are concentrated in the Bangkok metropolitan area. Additionally, there is a lack of comprehensive information on service-providing agencies, tools/equipment, and accessible service hours.

Addressing these challenges aligns with the national strategy under the 2018-2037 master plan, particularly in the area of research and development and supporting factors. The plan emphasizes the importance of modern science and technology infrastructure for the country's development. Establishing easily accessible and usable infrastructure for science, technology, research, and innovation is seen as crucial for enhancing the country's competitiveness globally.

In pursuit of these goals, the government aims to develop and elevate institutions in the science, research, and innovation sectors to meet national objectives. The "Science, Research, and Innovation Plan 2023-2027" focuses on developing and upgrading institutions to meet the country's goals effectively, aligned with international standards. Under the sub-plan N46 (S4P22), efforts are made to promote information awareness and access to science and technology services from research and innovation institutions conveniently and widely.

To enhance awareness and accessibility to science and technology services,

Suranaree University of Technology has initiated a project. The project aims to promote awareness and access to science and technology services provided by institutions in the science, research, and innovation sectors. The goal is to improve access efficiency, stimulate industrial utilization of infrastructure, and enhance the impact on the country's research and innovation capabilities. This project is expected to positively influence future research and innovation endeavors in the country.

Objectives:

1. Promoting the science and technology services in Thailand.

2. To establish mechanisms or guidelines for creating awareness and facilitating access to science, research, and innovation services in Thailand.

Progress/Findings/Results:

The project promoting the science and technology services in Thailand. The operational status can be summarized as follows.

1. Study and Development of Smart Search System: Currently, a study and analysis have been conducted to design and collect data for developing a Smart Search system to enhance awareness and access to science and technology services. The system aims to provide users with easier access to information about science services. The concept involves developing a tool for information search and service provision in science. Users can easily access significant and interesting science and technology information. The system employs data analytics technology and processes, covering services from 12 scientific units within the NSTDA. The database efficiently supports search commands, ensuring the most relevant results for users. A testing phase has been initiated to gather user feedback for further enhancements.

2. Awareness and Access Promotion Activities: This activity focusing on driving 10 target industrial groups.

(1) The training seminar promoting awareness and access to services and technology. Currently in operation.

(2) The marketing activities (Roadshow/Event Marketing) aimed at promoting awareness and access to services in the fields of science, research, and innovation at national-level exhibitions have been successfully completed. There were two events as follows:

- Thailand Lab International, Bio Asia Pacific, and FutureCHEM 2023: Dates: August 6 - 8, 2023. Venue: BITEC (Bangkok International Trade & Exhibition Centre), Bangna.

- The Foodism Show 2023: Dates: December 7 - 10, 2023. Venue: IMPACT Exhibition and Convention Center, Muang Thong Thani.

3. The Press Tour activity is conducted to promote awareness and facilitate access to science, research, and innovation services. Currently in operation.

Conclusion:

The overall progress of the project to promote awareness and access to services in the field of science and technology by the institution focused on science, research, and innovation in the country is at 34%. A summary of the progress in each activity can be outlined as follows:

1. Study and Development of Smart Search System:

2. Awareness and Access Promotion Activities: (1) The training seminar promoting awareness and access to services and technology currently in operation. (2) The marketing activities (Roadshow/Event Marketing) currently Complete.

3. The Press Tour activity currently in operation.

Current Output:

1. Smart Search System1 1 system**.**
2. Upgraded workforce with access to services in science, research, and innovation: 500 individuals.

Challenges/Problems and Possible solutions:

Future plan:

API-NET: Collaborative Network for Synthesis Technology towards Antiviral Active Pharmaceutical Ingredients

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 50%

Abstract: The API-NET project is a multidisciplinary initiative designed to innovate Active Pharmaceutical Ingredients (APIs) production, fostering a Triple Helix Model of collaboration among academia, industry, and government. The project investigates the local API market, advances manufacturing technologies, undertakes intellectual property studies of key molecules, and emphasizes capacity building within the pharmaceutical sector.

Rationales/Problem statements: The pharmaceutical industry faces challenges in innovation, local market dynamics, and sustainable drug production. The API-NET project addresses these by establishing a collaborative network among NSTDA, GPO, and PTT, aiming to develop a competitive edge in API synthesis and contribute to Southeast Asia's drug self-reliance.

Objectives: API-NET aims to create a robust Triple Helix Model to streamline innovation in API production and ensure sustainable national drug availability, focusing on collaboration, technological advancement, IP analysis, and human resource development.

Progress/Findings/Results: Within six months, API-NET established a Triple Helix network, analyzed institutional roles, and highlighted key bilateral relations essential for innovation. A detailed local market and supply chain study revealed growth opportunities and challenges. Technological exploration in continuous production and enzymatic processes is underway, complemented by a comprehensive IP study on selected molecules. Capacity building initiatives have also been launched to enhance expertise in API synthesis.

Conclusion: API-NET has made significant strides in promoting collaborative innovation in API production, with a focus on developing a Triple Helix Model, exploring new manufacturing technologies, and building intellectual capital.

Current Output: The initial phase has resulted in the establishment of a Triple Helix network and a framework for a proposed joint venture, setting the stage for ongoing advancements in API synthesis.

Challenges/Problems and Possible solutions:

Challenges include ensuring effective communication and role clarification among stakeholders. Also, this could be possible delay from e-learning platform for up-skill/re-skill course due to operation system maintenance.

Future plan:

Future plans include a detailed analysis of the Triple Helix model, initiation of pilot projects for selected technologies, and expansion of training programs to upskill the workforce in API production.

Potential Development on Testing and Production Services Compliance International Standard for Herbal Industrial

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 57%

Abstract:
This project had the objective to development the potential of services on testing and production compliance to national standard such as GLP and GMP. The development was including the safety evaluation compliance OECD GLP, efficiency test on 3D models, and herbal product manufacturing following Asian GMP. For 6 months progressive, the OECD Test No. 442E: *In Vitro* Skin Sensitisation: The Interleukin-8 Reporter Gene Assay (IL-8 Luc assay) and OECD Test No. 432: *In vitro* 3T3 NRU phototoxicity test was processed and announcement on OECD GLP documentation at 17 August 2023 and 30 August 2023**.** The efficacy test on 3D models were development with verified Human Oral Epithelium (HOE) tissue and Reconstructed Human Pigmented Epidermis (RHPE) Tissue. Wound healing test was carried out on HOE and depigmentation was conducted on RHPE. The efficiency test protocols were settled of appropriate dose, time and analysis result in control group. The pilot production development was carried out on standard of manufacturing. The lay out of manufacturing for co-operation with cosmetic and cosmeceutical was developed and was approved from Thai FDA.

Rationales/Problem statements:
According from the key result of N45P22 to reducing the gap between Thailand Research Institute and International benchmark Institute. TISTR was benched with Denish Technology Institute (DTI) in the area of S&T services to support entrepreneur. Therefore, the main area to development is increasing the potential of total solution services such as laboratory standard and up-scaling production plant for commercialize. Thailand is the largest market for cosmetics in ASEAN and top 20 in the world. Now a day, the significance cosmetics consumers place on value will drive the importance of safety and quality. The cosmetic products safety is emphasized in the global market and need the standard method for evaluation. OECD guide line is the global standard method and Thailand is the non-member MAD of OECD thus the safety data from OECD GLP laboratory in Thailand was acceptable in many countries. The new skin technology are 3D models were replacement of animals and human for proven effectiveness of products. Also in Thailand, Thai FDA announcement for a new category of herbal products “Herbal Cosmeceuticals” and they acceptance the efficiency data from 3D models. Although, the problem of Thai SMEs in cosmetic industries are lacking for the cosmeceutical manufacturing therefore the manufacturing prototype of co-operation between cosmetic and cosmeceutical was necessary to support the increasing of market competitiveness for Thai SMEs.

Objectives:
To development the potential of services on testing and production compliance to international standard.

Progress/Findings/Results:
The 8 months progress report covering with 2 parts of development as below;

1. Development for testing services
   1.1 Completed to verify and develop standard operation procedure (SOP) in skin

sensitization following OECD Test No. 442E: *In Vitro* Skin Sensitization: The Interleukin-8 Reporter Gene Assay (IL-8 Luc assay). The SOP was applied in OECD GLP system and sign by Test Facility. Management (TFM).

1.2 Completed to verify and develop standard operation procedure (SOP) in phototoxicity following OECD Test No. 432: *In vitro* 3T3 NRU phototoxicity test. The SOP was applied in OECD GLP system and sign by Test Facility. Management (TFM).

1.3 The efficiency test on 3D models for wound healing on human oral epithelium tissue was development. The protocol for handling tissue, sectioning and staining were complete. The method of stimulating of wound, inflammation and analysis are developing.

1.4 The efficiency test on 3D models for depigmentation on reconstructed human pigmented epidermis was development. The protocol for handling tissue, sectioning and staining were complete. The method of sample incubation time, melanin analysis and melanosome expression are developing.

2. Development for up-scaling services

2.1 The equipment for essential oil extraction was adjusted and extraction was protocol development. Hydro-distillation technique was applied and yield form 1:1 of ginger and water was 0.14%. Chemicals profile was analyzed by GC and found that the citral is the major component in ginger oil.

2.2 Development of conditions for ginger essential oil with nano emulsion technique in pilot scale at GMP manufacturing. Successfully incorporated ginger essential oil, a poorly soluble active compound, into o/w nanoemulsion by high-shear emulsification method. The nanoemulsion system consisted of Isopropyl myristate (IPM) as oil phase, Tween® 80 Cremophor® RH40 surfactant, and co-surfactant, respectively. The obtained ginger oil-encapsulated nanoemulsion presented in nano-droplet sizes with narrow size distribution and exhibited excellent physical stability under stress conditions.

2.3 The lay out of a co-production facility for cosmetics and herbal cosmeceuticals was approved by Thai FDA. The registration for certified was processed.

Conclusion:

Current Output: (for example: Publication/patent/prototype)

1. 2 SOPs for OECD GLP
2. 1 layout for co-production of cosmetics and cosmeceuticals facilities
3. 2 set of equipment for testing and up-scaling

Challenges/Problems and Possible solutions:

The problems of manufacturing development are long process on procurement. Another problem is the complicated process of Thai FDA approval.

Future plan:

1. Certify assessment of OECD GLP facility test for cosmetics products from Bureau of Laboratory Quality Standards**,** Department of medical Science, Ministry of Public Health.
2. Prototype of co-production manufacturing for cosmetics and cosmeceuticals according to GMP standards.

Strengthen Department of Science Service (DSS) to become a Leading Conformity Assessment Body (CAB) to Achieve the Sustainable Development Goal

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Project duration: 5 years, from 2023 to 2027
Current progress: 20%

Abstract:
Conformity assessment is the procedure ensuring confidence of consumers and manufacturers regarding the conformity of products. DSS is one of Thai government agencies working as a conformity assessment body in a role of the service center providing a board range of laboratory tests. To strengthen DSS capabilities in services to better meet increasing future global demands such as environmental and health concerns, the expertise of scientists is very crucial factor in this success. Therefore, DSS aims to develop staff potential through on-site project collaboration with experts from the benchmark institutions to acquire advanced knowledge in the development of new testing methods that address Thailand's needs and can be internationally benchmarked in three areas where services are not available in Thailand: micropollutants in environments, the efficiency of biomaterials, and PFASs. Herein, four high-rank scientific research institutes which are the benchmark institutions in the project consist of BAM, FAU, NMIJ and NIST.

Rationales/Problem statements:
Strengthening of NQI in terms of conformity assessment is one of DSS missions**.** This pillar of NQI presents that the quality of product or service meets the requirements of a standard**.** Therefore, the capability of conformity assessment body (CAB) is very crucial factor to provide the reliable test results to customers enhancing the market competitiveness. To be a leading CAB in Thailand, DSS aims to develop staff potential in order to expand laboratory services to meet global demands**.** The expertise of scientists is very crucial factor in this success. Therefore, DSS aims to develop staff potential through project collaboration with experts from high- rank research institutes to acquire advanced knowledge in the development of new testing methods for micropollutant and PFAS in addition to the biomaterial efficiency evaluation regarding to global concerns in environmental issues and human health that may play an important role in international trade in the future.

Objectives:
1. To strengthen DSS capability as an excellent analysis center for conformity assessment.
2. To develop the skill and knowledge of the DSS staffs for analysis methodology based on advance instrumental technique.
3. To seek collaboration and network of science, research, and innovation with world-class organization or institution for conformity assessment body to correlate with the international benchmark in similar burdens.

Progress/Findings/Results:
1. DSS has been coordinating, physical meeting, and online meeting to discuss with those organizations to achieve the skill development road map. Coordination and discussion with high-rank institute/organization is to find the collaboration and knowledge transfer agreement via Memorandum of Understanding (MOU). Since DSS plans to be a Leading Conformity Assessment Body (CAB) and benchmarks with the below institutions;

1.1 Bundesanstalt für Materialforschung und -prüfung (BAM), Germany

Physical meeting at Germany (9-18 June 2023) In this meeting, DSS achieved the

potential discussion with BAM about the excellent center for method development and challenge research for change the world. The matching scope of training program of DSS staff is divided into 2 interested area correlated to the work division in BAM. There are Division 1.1: Inorganic trace element for analysis of perfluoroalkyl and polyfluoroalkyl Substances (PFASs) and Potential toxic elements (PTEs) ex. Speciation analysis of As, Cr, Hg and Division 1.8: Environmental Analysis for contaminants of emerging concern (CECs).

Online meeting (24 October 2023) the summary of this meeting, DSS will be send 2 staffs to attend the training in Division 1.8: Environmental Analysis under supervision of Dr. Björn Meermann, the tentative schedule in February 2024. The training program consist of the method development for analysis of endocrine disruptive compounds (EDCs) such as estrogen (one of CECs) and antibiotics such as diclofenac and tetracyclines. The BAM-DSS agreement will be carried out using Guest contract and Memorandum Of Understanding (MOU).

1.2 Institute of Biomaterials, Department of Materials Science and Engineering, Friedrich-Alexander Erlangen-Nuremberg (FAU), Germany

DSS interested in synthesis of biomedical materials and had a plan to 1) development of advance laboratory for in-vitro testing of biomaterials (e.g. bioactivity, cytotoxicity, cell test and bacterial resistance etc.) and 2) staff exchange program between DSS and FAU.

1.3 National Metrology Institute of Japan (NMIJ) and National Institute of Advanced Industrial Science and Technology (AIST), Japan

DSS aims to analysis of PFASs which may contains in food containers and to benchmarks the standard operate procedure to Organic Analytical Standards Group and Environment Management Research Institute of NIMJ/AIST. The staff training program is about the determination of PFASs (i.e. perfluorooctanoic acid (PFOA), perfluorooctanesulfonic acid (PFOS), Perfluoroundecanoic acid (PFUdA), and perfluorododecanoic acid (PFDoA)) in seafood and seafood product.

1.4 National Institute of Standards and Technology (NIST), USA (22 September – 1 October 2023)

DSS seek the cooperation with Material Measurement Laboratory (MML) for analysis of polyfluoroalkyl substances (PFAS) residue and contaminated in food and environments.

2. Attending academic conference “IUPAC 2023” at Netherlands that is fit with the project purpose is to find the opportunity for environmental research network. In this conference consisted National Representatives in Division VI - Chemistry and the environment (19-20 Aug 2023) and IUPAC general assembly 2023 (18-25 Aug 2023). The academic network is expanding to who work in field of environment for micropollutants (especially, CECs and PTEs.) Additionally, the work shop was served to the scientists and researchers for experience sharing and learning of innovation as follows;

   1. The Environment, health, and food safety impact of microplastics

   2. Bioavailability and significance of endocrine disruptive compounds (EDCs) in tertiary effluent and Impact on water reuse.

Conclusion:

For achieving the higher range of GQII and GCI, DSS has proceeded the strengthen potential of CAB in the fields of micropollutants **(**CECs, PTEs, microplastic**)**, PFAS **(**food and food contact material, environmental**)** including biomedical material**.** Therefore, benchmarking with high range organizations **(**BAM, FAU, NIST, NMIJ**)** by making MOU and research cooperation will be arranged**.** Then, developing standard testing method that proper for Thailand will be conducted**.** Eventually, the knowledge about standard method will be transfer to streak holder for enhance the certified body lab of the country**.**

Current Output: None

Challenges/Problems and Possible solutions:

Appointment meetings with BAM experts and making their final decision mostly are time consuming processes because the experts who participate in the meeting work in different divisions but work together for designing specific work plan for DSS staff. For Given that the staff members have tight schedules resulting in a late DSS and BAM meeting. The meeting, originally scheduled for an earlier date, has been rescheduled to October 2023, leading to subsequent delays and complexities in finalizing the training agreement. Therefore, the timeline for DSS's work plan has also been postponed resulting in lack of experimental results at the present.

Future plan:

To attend the training program with benchmark organizations (BAM, FAU, NIST, NIMJ) as follows:

Year 2024 Analysis of estrogen in wastewater, PFAS in seafood and seafood product, and synthesis of biomedical materials and ATMP.

Year 2025 Analysis of microplastic and PFAS in environment, PFAS in seafood and seafood product (cont.), and performance evaluation of 3D-porous scaffold.

Year 2026 Analysis of PFAS in environment and in food and food contact materials, and Laboratory for biomedical materials and ATMP set up.

Analysis Ready Data of Earth System Science and Essential Climate Variables for PM2.5 Monitoring and Forecasting

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 57.92%

Abstract:
This project aims to enhance the efficiency of PM2.5 monitoring and forecasting platform with Analysis Ready Data of Earth System Science and Essential Climate Variables (ECVs) in both spatial and temporal terms, as well as develop and enhance the capacity of GISTDA, Thailand space agency, to be internationally recognized in research and innovation that meet the country's goals in PM2.5 management.

Rationales/Problem statements:
Monitoring the situation of changes that will occur in the near future requires the use of Earth System Sciences data. In particular, data obtained from satellites that continuously and covers the entire area of Thailand for enhancing the ability of response and adaptation to the rapidly changing in global situations at different aspects. However, Thailand currently lacks an Earth System Science and Essential Climate Variables (ECVs) dataset for the management of disaster, natural resources, ecosystems, and the environment that cover all dimensions in a timely manner. Relying on geospatial technology and satellite data, it can therefore be used for long-term studies to identify the environmental changes. The spatial and temporal comparisons can be made by using the ECVs extracted from satellite data. It is used as data for calibrating and validating of the climate models. In addition, satellite data can be used in conjunction with geo-informatics technology and statistical data to study and analyze the variables for climate forecasting, studying, tracking, and examining trends in extreme weather conditions and the impacts that will occur both regionally and globally.

Objectives:
1) To develop and enhance the capacity of GISTDA, Thailand space agency under the Ministry of Higher Education, Science, Research and Innovation, to be internationally recognized in research and innovation that meet the country's goals in PM2.5 management
2) To create a mechanism for collaboration between agencies in the development of science, technology, research and innovation both domestically and internationally
3) To enhance the efficiency of PM2.5 monitoring and forecasting platform with Analysis Ready Data of Earth System Science and Essential Climate Variables in both spatial and temporal terms

Progress/Findings/Results:
During the 6-months of project progress, the research team has developed a database of ECVs from satellites and reanalysis data (ERA5), especially the variables that related to PM2.5 concentration. The ECVs database are now providing through a prototype of online services systems. In order to develop and enhance the capacity of the organization, the research team has arranged a study visit to research and innovation institutes in the United States that related to Earth System Science, space technology, geo-informatics, environmental science, and climate and atmospheric science. The institutions are included;

Cooperative Institute for Research in Environmental Sciences (CIRES), National Center for Atmospheric Research (NCAR), Laboratory for Atmospheric and Space Physics (LASP), and Environmental Data Science Innovation & Inclusion Lab (ESIIL). The results enhance the capacity and knowledge of the research team in various fields, especially in climate and environment, which is an important basis for studying environmental and ecological conditions to understand global science and respond to climate change. Moreover, the results from a study visit have led to the collaborations between experts and researchers from international agencies to develop international cooperation in other areas. In addition, the team has conducted a workshop on Earth System Science and Essential Climate Variables (ECVs) for air pollution monitoring and prediction by atmospheric physics experts from Silpakorn University, and a technical workshop on developing of mobile applications for climate monitoring and forecasting in order to enhance the capability of GISTDA's researcher.

Conclusion:

In order to enhance the efficiency of PM2.5 management in Thailand, this project apply the Earth System Science and Essential Climate Variables (ECVs) with geospatial technology to monitor and forecast PM2.5 in both spatial and temporal terms. The database of ECVs from satellites data, especially the variables that related to PM2.5 concentration, is developed. In addition, this project focus on enhances the capacity of GISTDA's researcher, in terms of skills and scientific knowledge for understanding the Earth System Science, to be internationally recognized in research and innovation that meet the country's goals in PM2.5 management.

Current Output: ECVs database/prototype of online database service/draft of manuscript

Challenges/Problems and Possible solutions:

Problems and obstacles that arise during the project are the variety of data, both spatial and temporal, as well as the different data formats, which affect the processing time.

Future plan:

The next activity of this project is to develop appropriated models for hourly PM2.5 forecasting for Thailand in order to enhance the efficiency of PM2.5 monitoring and forecasting platform. In addition, the project focus on enhances the capacity of GISTDA's researcher through a technical workshop on model development for PM2.5 prediction by experts from the Japan Aerospace Exploration Agency (JAXA) or Japan Meteorological Agency (JMA). This is also to create the collaborations between experts and researchers from international agencies to develop international cooperation in the aspect of Earth System Science.

BRAINPOWER CONGRESS 2023

ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Omics Technology, Immunology, Tissue Engineering)

Discovery and Development of Biomarkers and Lead Compounds towards Personalized Medicine in Cancer

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Project duration: 3 years, from 1 September 2022 to 31 August 2025
Current progress: 30%

Abstract:
Cancer, a leading global cause of mortality, presents challenges in treatment, especially in advanced stages and against drug resistance. The limitations in diagnosis and effective treatment are further enhanced by the genetic diversity and lifestyle variations within the population. Therefore, this research aims to focus on two strategies. First, the finding of biomarker that can predict severity, treatment efficiency, and drug resistance. We analyzed clinical risk score and identified biomarker of colorectal cancer (CRC) and head and neck squamous cell carcinoma (HNSCC) in Thai cancer database from Ramathibodi, Siriraj, and Songklanagarind Hospital. Second, screening and development of lead compounds as new drugs for CRC and HNSCC. To this end, we used a molecular docking and computational analysis to explore the inhibitor of TMEM16A and PD1/PD-L1. Furthermore, rational designed and synthesis of proteolysis targeting chimera (PROTAC) showed promise in targeting CRC K-ras mutation. These drug discovey approaches expected to improve treatment precision, reduce side effects, and enable a more efficient and cost-effective personalized healthcare system.

Rationales/Problem statements:
The conventional drug discovery model faces challenges due to the diverse genetic makeup and lifestyle variations among the population. The current one-size-fits-all approach often leads to suboptimal treatment responses and increased healthcare costs. Integrating personalized medicine using data on phenotypes and genotypes into drug discovery is crucial to address these issues. The Genomics Thailand project that decodes the genetics of Thai people will be important in understanding genetic diversity and discovering genes related to disease. The use of genetic decoding technology has produced a wealth of patient information which can be analyzed to predict health and disease and help develop appropriate medicines and medical devices for each individual. The research project focuses on finding biomarkers to predict drug response and cancer recurrence in head and neck cancer and colon cancer patients. This study could lead to develop the most friendly and effective medicines and treatments for each patient in Thailand.

Objectives:
This research aims to establish clinical risk score and identify biomarkers that can be used to predict the severity, recurrence, and resistance to chemotherapy in patients with colorectal cancer and head and neck cancer. Additionally, it attempts to investigate novel therapeutic targets and small-molecule inhibitors of TMEM16A and PD1/PD-L1. Finally, the objective

is to further develop proteolysis targeting chimera (PROTAC) for the purpose of specifically targeting and degrading K-ras mutant proteins.

Progress/Findings/Results:

The objective of this project is to develop biomarkers that that can accurately predict the severity, recurrence, and resistance to chemotherapy in CRC and HNSCC. The identification of novel therapeutic targets and small molecule drugs has the potential to facilitate the advancement of innovative treatments for severe or chemotherapy-resistant malignancies. During the first year, researchers examined biomarkers and clinical signs. Furthermore, computer analysis was used to screen for biologically active compounds. The research progress is following.

1) The researchers enhanced the study of The Clinical Risk Score by classifying patients as either locally advanced or recurrent/metastatic based on comprehensive patient data from a multicenter database. This outcome may indicate the attributes of head and neck cancer among a population of 6300 patients in Thailand during a period of 13 years.

2) MALAT1 polymorphisms, in predicting the severity of head and neck cancer, the SNP position rs529361751, a position previously reported by investigators to be associated with overall survival (OS) and progression-free survival (PFS) of patients, met the criteria from this analysis. Importantly, the SNP position was significantly associated with OS and PFS of HNSCC patients.

3) Multi-omics analysis and functional study of biomarkers of HNSCC, and CRC showed that the expression of SLC3A2, FAT1, KMT2D, ITPR3 and NAT10 genes, along with the factors such as smoking, gender, stage of the first cancer (index tumor), alcohol consumption, and patient age, are significantly associated with cancer recurrence at a new location (known as second primary malignancy; SPM) ($p > 0.05$). As a result, total of 5 models can be designed and can be expressed as a weighted multiplier equation. These models exhibit a high level of sensitivity and accuracy, as well as true positive rates, in accurately predicting cancer recurrence in SPM.

4) Molecular docking analysis for the screening and development of a TMEM16A inhibitor for HNSCC treatment revealed three promising candidate inhibitors, specifically 164, 165, and 167. Out of them, the compound with the highest potency, 164, was chosen for further characterization. According to the molecular dynamic modelling analysis, 164 exhibited a greater number of atom interactions compared to the previously reported pore blocker, 1PBC. Furthermore, compound 164 exhibited superior MMGBSA energy values compared to 1PBC, suggesting that it has potential as a TMEM16A inhibitor for further investigation in the context of head and neck cancer.

5) For development of K-Ras proteolysis targeting chimera (K-Ras PROTAC) for the treatment of drug-resistant colon cancer, the total of 3 derivatives of PROTACs have been synthesized, starting with 2 products of Idasanutlin E3 ligands (Idasanutlin-PEG3-Sotorasib and G12Si-PEG3-Idasanutlin), including 1 molecule which is a negative control for KRAS G12C mutation.

6) For development of small molecule PD-L1 inhibitors for the treatment of drug-resistant CRC, the investigation was carried out using cell-based luminescence assay. It was found that there was 1 substance from Chemdiv library (C539-0555) and 1 crude herbal extract has the effect of inhibiting PD1/PD-L1 interaction similar to the standard substance BMS1166.

Conclusion:

This study, we integrated a range of methodologies including develop the clinical risk score, identified biomarker, multi-omics analysis, molecular docking and computational analysis, as well as, rational design and synthesis of K-ras PROTAC. The current result showed that

a time to recurrence interval (TTRI) factor is an important criterion for clinical trial classification. The SNP position rs529361751 is a potential prognostic biomarker, and also SLC3A2, FAT1, KMT2D, ITPR3 and NAT10 could be candidate biomarkers as well as a potential protein target for head and neck cancer. Furthermore, candidate TMEM16A and PD1/PD-L1inhibitor was identified. Finally, the K-Ras PROTAC prototype was successfully synthesis.

Current Output:

1. 4 manuscripts (in preparation)
2. 2 international conferences
    1. ESMO meeting 2023, Madrid, Spain, Oct 20-24, 2023.

Changing Landscape of Head and neck squamous cell carcinoma (HNSCC) Treatment and Survival in Thailand: A 13-Year Multicenter Retrospective Study of 6,319 Patients. Nuttapong Ngamphaiboon, Arunee Dechaphunkul, Chanida Vinayanuwattikun, Pongwut Danchaivijitri, Thanaporn Thamrongjirapat, Anussara Prayongrat, Tanadech Dechaphunkul, Rungarun Jiratrachu, Poompis Pattaranutaporn, Chuleeporn Jiarpinitnun, Jiraporn Setakornnukul

2. ESMO meeting 2023, Madrid, Spain, Oct 20-24, 2023. Early Recurrence, Time-to-Recurrence, and Recurrence Patterns: Assessing Their Impact on Survival Outcomes in Recurrent/Metastatic Head and Neck Squamous Cell Carcinoma (R/M-HNSCC) Patients. Pasvich Pitakpaiboonkul, Chuleeporn Jianpinijnan, Poompis Pattaranutaporn, Nuttapong Ngamphaiboon

Challenges/Problems and Possible solutions:

1. The Sanger sequencing technology has limitations in its capacity to decode repeated DNA sequences. Hence, the research team will investigate the biological functionality of Single Nucleotide Polymorphisms (SNPs) that cannot be identified using the Sanger sequencing approach in order to gather evidence and establish this SNP as a biomarker.
2. The production of K-Ras PROTAC is more complicated than expected, resulting in a slight delay in the progression of the procedure. The issue was resolved by making necessary modifications to the synthesis strategy, enabling its current implementation.

Future plan:

Research plan for the second year is as followed. First, data analysis on multi-omics database will be performed to identify biomarker and novel protein targets while exploring their biological function. Second, establishment and refinement of a culture protocol for the CRC & HNSCC organoid library will be done. Third, characterization of inhibitors of TMEM16A and PD1/PD-L1 including structure-activity relationships (SAR), toxicity assessments, and pharmacokinetics will be performed. Finally, efficacy of K-Ras PROTAC will be evaluated.

Notch Signaling Regulates the Process of Endothelial Ablation in Pancreatic Ductal Adenocarcinoma

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Project duration: 2 years, from 1 November 2021 to 31 October 2023
Current progress: 80%

Abstract:
Pancreatic ductal adenocarcinoma (PDAC) is an aggressive malignancy, which exhibits reduced vessel number and thin collapsed vasculature that contributes to compromised sensitivity to chemotherapy. Previous studies demonstrated that tumor endothelial cells are ablated by PDAC cells; however, the mechanism of endothelial ablation remains elusive. Therefore, we investigated effects of PDAC-conditioned media or PDAC direct cell contacts on the behaviors of HUVECs. We found that PDAC-conditioned media exerted minimal effects on HUVEC proliferation, migration, and network formation. Interestingly, our co-culture model showed increased apoptotic and decreased proliferating endothelial cells in proximity to PDAC invasion, implicating that a direct cell-cell contact between tumor endothelial and PDAC cells was required for endothelial ablation. Furthermore, we identified that Dll4-Notch signaling may be a potential mediator of endothelial ablation. Our study provides important insight into the mechanism of PDAC hypovascularity and may lead to the improved strategy of PDAC chemotherapeutics.

Rationales/Problem statements:
PDAC presents a significant public health problem. Patients exhibit a poor survival rate due to its tolerance to conventional therapies. Previous studies demonstrated that anti-angiogenic treatment revealed inefficacies on advanced PDAC patients. PDAC poor responsiveness to chemotherapeutic drugs is caused by its hypovascularity, which is characterized by reduced overall vessel density with impaired vascular integrity. During PDAC progression, vascular endothelial cells undergo apoptosis, leaving behind only tumor cells. These incidents might contribute to limit the drug therapeutic delivery to the tumor cells. PDAC patients with high CD31 expression have a higher overall survival rate because of their better response to therapeutic treatment. In this study, we investigate the role of PDAC regulating endothelial cell behavior through paracrine signaling and direct contact. Understanding PDAC-EC communication will provide an insight to tumor hypovascularity and improve future PDAC therapeutics.

Objectives:
- To investigate hypovascularity and vasculogenic mimicry in PDAC
- To determine the effects of PDAC cells on HUVEC characteristics
- To identify and analyze anti-endothelial factors from PDAC by proteomic analysis
- To validate the function of anti-endothelial factors from PDAC

Progress/Findings/Results:
Conditioned medium from PANC-1 inhibited HUVEC cell proliferation.

As PDAC tumors notably manifest hypovascularized characteristics, we hypothesized that PDAC cells might provide an inhibitory effect on HUVEC cell growth as shown in Figure 1. The breast cancer cell line MDA-MB-231 was used as control for cancer cells that have been previously shown to activate endothelial cells and induce angiogenesis.

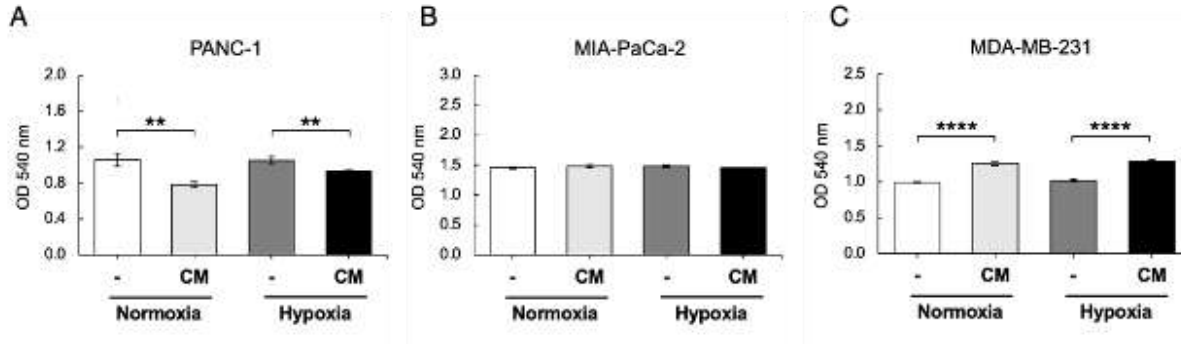

Figure 1. HUVEC cell proliferation after 24 hours post-treated with conditioned media under two different conditions.

PDAC-conditioned media decreased p-Src, p-Akt, and p-PLC in HUVECs.

We further investigated the effects of PDAC paracrine signaling on downstream pathways in HUVECs by Western blot analysis as shown below. These phosphoproteins are downstream mediators in the VEGFR-2 signaling pathway. Our Western blot results showed that PDAC-conditioned media significantly decreased the levels of p-Akt and p-Src that are important for endothelial cell survival and p-PLC which is necessary for endothelial cell proliferation, confirming the negative effects of paracrine signals derived from PDAC.

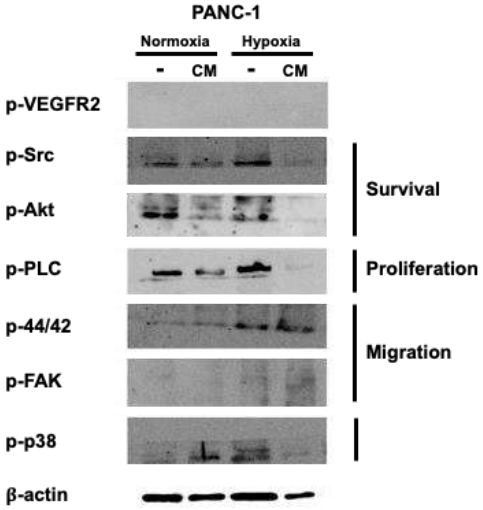

Figure 2. PANC-1-conditioned media reduced downstream targets that are necessary for cell survival and proliferation.

Endothelial ablation process required cell-cell direct contact-dependent manner between PDAC and endothelial cells

To investigate the process of endothelial ablation by PDAC tumor through cell direct contact, we generated a stable GFP-expressing HUVEC for co-culture experiments. We found that PDAC-HUVEC co-culture increased Caspase-3 and decreased Ki-67 signals

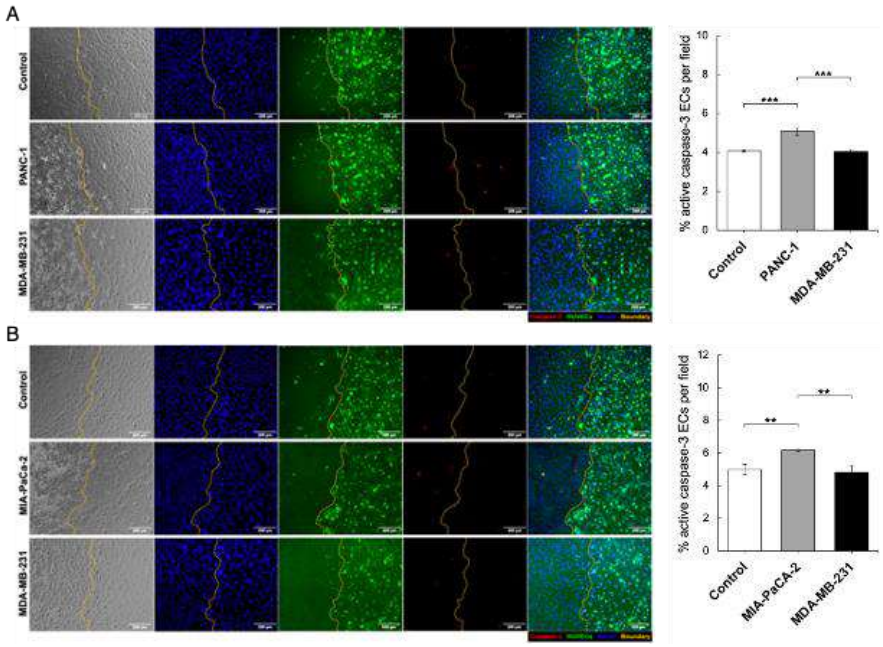

Figure 3. An increase of apoptotic HUVECs was coincided with PDAC cell invasion.

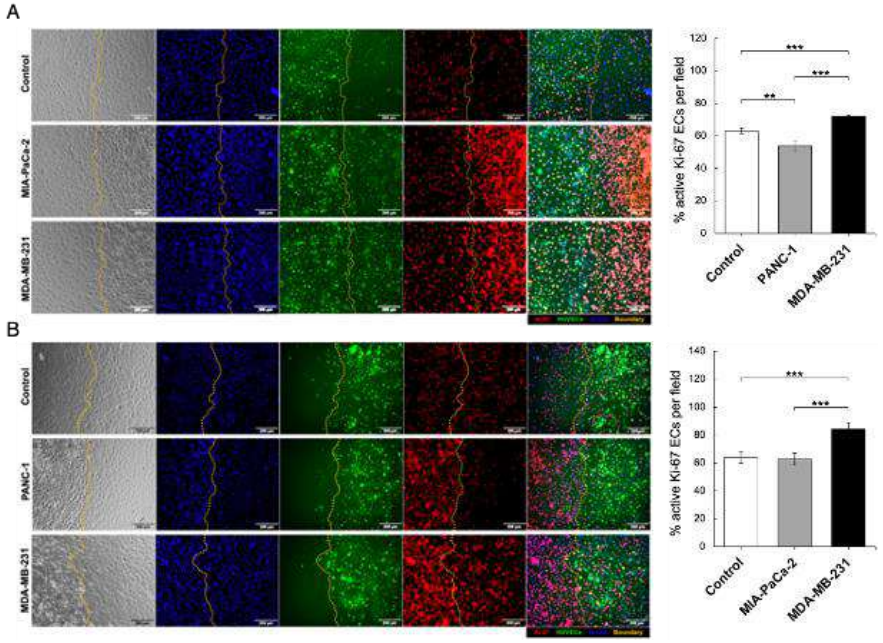

Figure 4. A decrease in proliferating HUVECs was coincided with PDAC cell invasion.

Conclusion:

Our data showed that VM incidence was correlated with tumor size and NOTCH1 expression and activity in PDAC and proved that Notch signaling plays a role in inducing VM formation by promoting the EMT process. Furthermore, Notch signaling regulates the process of endothelial ablation which results in the characteristics of PDAC hypovascularity by upregulating Notch ligand, DLL4.

Current Output:

1. Benjakul N, et al. Notch signaling regulates vasculogenic mimicry and promotes cell morphogenesis and the epithelial-to-mesenchymal transition in pancreatic ductal adenocarcinoma. PLOS One. 2022;17(12):e0279001.
2. Eamsaard C, et al. Notch signaling regulates the process of endothelial ablation in pancreatic ductal adenocarcinoma. *Manuscript in preparation*.

Challenges/Problems and Possible solutions: None

Future plan:

The second manuscript will be completed within the next two months and should be ready for submission.

Development of Novel Therapy for β-Thalassemia by Creating Hereditary Persistence of Fetal Hemoglobin (HPFH) Genotypes Using CRISPR/Cas9 Genome Editing Technology

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 65%

Abstract:

Clinical studies have shown that co-inheritance of hereditary persistence of fetal hemoglobin (HPFH), a naturally occurring condition with elevation of fetal hemoglobin (HbF; $\alpha_2\gamma_2$) throughout adult life, can ameliorate the clinical severity of β-thalassemia. French HPFH is a deletional HPFH that strongly elevates HbF level up to 35% in heterozygotes. Here, we used CRISPR/Cas9 to create a 10.6-kb large deletion in the β-globin locus (5′ mini French) that mimics the 5′ half of the French HPFH to reactivate HbF expression. Delivery of Cas9 and paired single guide (sg) RNAs targeting left and right breakpoints of the deletion into the $CD34^+$ hematopoietic stem/progenitor cells (HSPCs) derived from β-thalassemia/HbE patients resulted in the generation of genome editing including large deletions, inversions, and small indels. This led to a robust increase in HbF level and amelioration of erythroid differentiation. The off-target analysis will be further investigated. These results provide a novel therapeutic strategy using CRISPR/Cas9 to reactivate HbF expression for β-thalassemia.

Rationales/Problem statements:

β-Thalassemia, one of the most common genetic blood disorders worldwide, is characterized by reduced or absent production of β-globin chain and adult hemoglobin (HbA), leading to anemia. Clinical studies have shown that co-inheritance of hereditary persistence of fetal hemoglobin (HPFH), a naturally occurring condition with elevation of fetal hemoglobin (HbF) throughout adult life, can ameliorate the clinical severity of β-thalassemia. A French HPFH is one of the deletional HPFH that strongly elevates HbF level up to 35% of total hemoglobin in heterozygotes. It is the 19.7-kb deletion extending from the γδ-intergenic region to the downstream of the β-globin locus. Here CRISPR/Cas9 genome editing technology was used to create a large deletion that mimics the naturally occurring French HPFH and two additional shorter deletions, 5′ mini French and 3′ mini French deletions, to reactivate HbF expression for the development of a novel therapeutic strategy for β-thalassemia.

Objectives:

The ultimate goal of this study is to develop the CRISPR/Cas9 to create large deletions in the β-globin locus for reactivating HbF expression for the treatment of β-thalassemia.

Progress/Findings/Results:

Induction of HbF expression in erythroid cells differentiated from genome-edited HSPCs of β-thalassemia/HbE patients

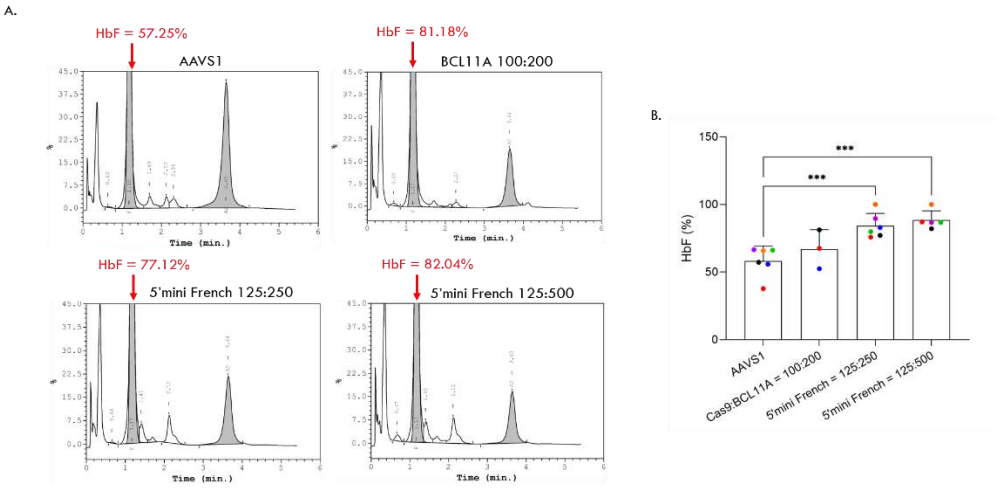

Figure 1. Robust HbF upregulation in β-thalassemia/HbE erythroid cells upon genome editing of the 5′ mini French.

HSPCs were electroporated with Cas9 and synthetic sgRNA ribonucleoprotein (RNP) complex at indicated amounts (pmol), and differentiated into mature erythroid cells. Hemoglobin composition was analyzed by high-performance liquid chromatography (HPLC). (A) Representative HPLC chromatograms of erythroid cells differentiated from 5′ mini French edited HSPCs. (B) The histogram represents the quantitative analysis of HbF. AAVS1, a control sgRNA targeting the AAVS1 safe harbor site; BCL11A, a sgRNA targeting the BCL11A erythroid-specific enhancer.

CRISPR/Cas9-mediated HbF induction improves differentiation of β-thalassemia/HbE erythroid cells

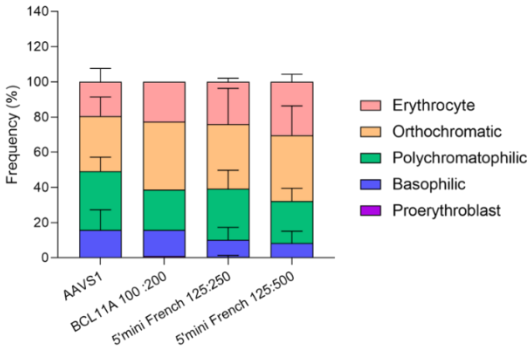

Figure 2. 5′ Mini French genome editing enhances β-thalassemia/HbE erythroid cell differentiation. Quantitative analysis of the erythroid subpopulations of edited HSPCs from β-thalassemia/HbE patients. Erythroid cell morphology was examined by modified Giemsa staining of cytospins.

Conclusion:

Genome editing by generation of 5′ mini French in HSPCs derived from β-thalassemia/HbE patients led to a robust reactivation of HbF synthesis and improvement of erythroid differentiation.

Current Output:

One patent and one manuscript are in preparation.

Future plan:

The off-target analysis of sgRNAs used to generate the 5′ mini French deletion will be further investigated. Moreover, smaller deletions within the 5′ mini French will be evaluated to identify the key region involved with HbF induction.

Eradication and Replacement of BCL11A Enhancer with β-Globin Gene for Simultaneous Induction of HbF and HbA in β-Thalassemic Erythroblasts

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Project duration: 3 years, from 1 November 2021 to 31 August 2024

Current progress: 55%

Abstract:

β-thalassemia is a genetic blood disorder caused by a mutation in the β-globin gene. The patients are incapable of producing β-globin which is a crucial component of adult hemoglobin (HbA, $\alpha_2\beta_2$). Therefore, β-thalassemia patients suffer from severe anemia due to an insufficient HbA in red blood cells. Recent studies have been showed that increased production of γ-globin could be substituted for the inadequate β-globin and assembles to fetal hemoglobin (HbF, $\alpha_2\gamma_2$). Moreover, many studies evidenced that the elevation of HbF levels in β-thalassemia patients associates with milder clinical phenotypes. BCL11A is a well-known γ-globin repressor and downregulation of BCL11A could significantly induce γ-globin and HbF production in erythroid cells. However, dysregulation of BCL11A in non-erythroid cells could cause unwarranted effects. Here, this study aimed to target the erythroid-specific BCL11A enhancer as an option for therapeutic induction of HbF in β-thalassemia. Non-pathogenic β-globin gene was engineered and used *in vitro* to replace the BCL11A enhancer in β-thalassemic erythroblasts. We believe that this strategy could simultaneous induce HbF and HbA levels in our model and could be applied for curing β-thalassemia in the near future.

Rationales/Problem statements:

Thalassemia is an important healthcare burden worldwide. Currently, living β-thalassemia patients are approximately 100,000 individuals in Thailand. Lifelong blood transfusion is the first supportive therapy for these patients to ameliorate anemia status. To date, the only curative therapy for the β-thalassemia patients is bone marrow transplantation (BMT). Autologous BMT with gene therapy is an alternative venue for β-thalassemia treatment. However, this technique is solely licensed abroad and limited further development in other countries including Thailand. To extend the usage in our country, this study determined new strategies for autologous BMT with gene therapy. BCL11A enhancer-specific dual gRNA and engineered β-globin template will then be investigated as an alternative platform for simultaneous induction of HbF and HbA levels in β-thalassemic erythroblasts.

Objectives:

This study mainly aimed to replace the BCL11A enhancer with an engineered human β-globin gene cassette using CRISPR/Cas9 system in β-thalassemic erythroblasts. By doing

that, the simultaneous restoration of HbF and HbA may be observed and the success of this study may provide additional gene therapy options for β-thalassemia treatments through an induction of HbF alone or in combination with HbA.

Progress/Findings/Results:

In the first year, we investigated the functional efficiency of six gRNA targeting human BCL11A enhancer (gRNA#1 to gRNA#6) in human erythroblasts (n=3) using ribonucleoprotein and electroporation. Of these, gRNA#2 (mean±SD; 96±2%) and gRNA#5 (mean±SD; 89±6%) showed maximal editing efficiency after Inference of CRISPR Edits (ICE) analysis. However, HbF levels were insignificantly changed when compared to the control (gAAVS1). This maybe due to the distal editing site of the gRNA to the GATA1 binding site within the BCL11A enhancer. Together, these two gRNA will be used in a dual form for eradication of the BCL11A enhancer in β-thalassemic erythroblasts.

In the second year, we engineered the two different non-pathologic human β-globin cassettes. Generally, human β-globin gene is located on chromosome 11p15.4 [NC_000011.10 (5225464..5227071)] and the length of the gene is 1,608 bp with three exons. However, the expression of human β-globin gene requires 5'-*cis*-enhancer which is the locus control region (LCR) and this region contains five hypersensitive sites (HS1-HS5). To engineer a non-pathologic human β-globin as a donor template for homologous direct repair (HDR) following CRISPR/Cas9 mediated genome editing, we therefore amplified a full-length β-globin gene (1,608 bp) from the genome of normal individual. In addition, the promoter (303 bp) and core region of HS2 (419 bp), HS3 (451 bp), and HS4 (419 bp) were also engineered to the 5'-end of the full-length β-globin gene using overlap extension PCR. This engineered β-globin gene was verified by Sanger sequencing and was named as a non-pathologic human full-length β-globin donor template (3,200 bp). We also replaced the full-length β-globin gene (1,608 bp) with the full-length β-globin cDNA (628 bp) amplified from the cDNA library of a normal individual. This generated a second donor template and was named as a non-pathologic human cDNA β-globin donor template (2,220 bp). To prevent a degradation of these two donor templates, each verified donor template was individually subcloned into a vector following a blunt-end ligation.

Conclusion:

Of these six gRNA, gRNA#2 and gRNA#5 were the two most efficient gRNA for editing BCL11A enhancer in human erythroblasts. Moreover, we are successfully engineered two non-pathogenic human β-globin cassettes for replacing the BCL11A enhancer in β-thalassemic erythroblasts. In the next phase, the two gRNA and the engineered β-globin cassettes will be utilized as a dual gRNA and donor templates respectively for replacement of the BCL11A enhancer and for simultaneous induction of HbF and HbA in β-thalassemic erythroblasts.

Current Output:

The most effective dual gRNA for removing BCL11A enhancer in human erythroblasts has been identified and two different engineered human β-globin gene cassettes have been produced.

Challenges/Problems and Possible solutions:

None

Future plan:

We will investigate the efficacy of the two engineered human β-globin cassette in β-thalassemic erythroblasts. BCL11A enhancer will be eliminated using the specific dual gRNA and the engineered donor templates will be substituted for the deleted BCL11A enhancer. Efficacy of the replacement may be enhanced by adding a compound that is able to increase the rate of HDR integration.

Induction of Adaptive Immunity against Childhood Solid Tumors Using mRNA Vaccine

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 70%

Abstract:

The oncohistone H3 lysine-to-methionine mutation at the position 27 (H3K27M) is a well-defined neoepitope found in diffuse intrinsic pontine glioma (DIPG). Likewise, the cell surface antigens glypican 2 (GPC2) and GD2 ganglioside are common tumor-associated antigens (TAA) found in glioma. By targeting neoepitopes and tumor-associated antigens (TAA), the cancer immunotherapy offers a great promise for childhood cancers. Strikingly, a combination between mRNA vaccines together with CAR T cells or with anti-PD-1 has been recently shown to improve treatment efficacy for ovarian cancer and melanoma, respectively. Therefore, the primary goal of the proposed work is to elucidate a possible role of mRNA vaccines encoding childhood cancer antigens including H3K27M, GPC2, and GD2 mimetic peptides in humoral and cytotoxic immune responses in animal models. The outcome of this proposed work will provide not only a fundamental knowledge of cancer immunology, but also novel therapeutic strategies aiming at cancer immunotherapy using mRNA vaccines.

Rationales/Problem statements:

Cancer vaccines developed from circular mRNA (circRNA) individually producing GD2 mimetic peptide, the neoepitope H3K27M, and GPC2 have been constructed. Particle size and polydispersity index analyses of the mRNA-LNP (lipid nanoparticles) formulations of GD2, H3K27M, and GPC2 mRNA-LNP indicated an optimal particle size and the homogeneity of the mRNA-LNP. Then, protein expression analyses of mRNA-LNP were performed for each immunization as per quality control. Subsequently, immunogenicity of individual cancer mRNA vaccines was tested using mice models. Lastly, an anti-tumor activity of a selected cancer mRNA vaccine was tested in immunocompetent mice bearing tumors.

Objectives:

To develop a cancer vaccine using a proprietary circular mRNA platform.

Progress/Findings/Results:

Among the three candidates, circGD2 did not yield an optimal protein expression, therefore being rejected for further analyses. Then, mice were immunized with circRNA-H3K27M or with circRNA-GPC2. The mice were immunized at weeks 0 and 3 with 5 or 10 μg of the circRNA-LNP. IgG levels of two weeks post-prime and post-boost sera were assessed by ELISA for testing anti-H3K27M or anti-GPC2 total IgG production. Spleenocytes were collected for ELISPOT and the generation of hybridoma clones. Though anti-H3K27M IgG was unable to detect in the mouse sera, a very high IgG level was observed for GPC2. H3K27M peptide-activated T cells producing IFN-γ were determined using IFN-γ ELISPOT assay. However, the circular mRNA encoding the H3K27M peptide neoepitope failed to induce strong T cell activation. Ongoing works aim at ELISPOT assay of GPC2 peptides and the development of GPC2 hybridoma and monoclonal antibodies.

Conclusion:

A cancer mRNA vaccine expressing GPC2 has been developed using a circular mRNA approach.

Current Output:

Seephetdee et al. (2022) Antiviral Research, Volume 204, 105370

Future plan:

To develop mouse models for cancers expressing GPC2 such as neuroblastoma (Neuro2a) and lung cancer (LLC1) and to subsequently test the cancer mRNA vaccine targeting GPC2 in the models.

However, in case of unforeseen circumstances, other mouse models bearing an intact immune system can also be developed, for example a BALB/C model bearing the aggressive murine breast cancer cells 4T1. GPC2 or other tumor-associated antigens can then be served as the target for a cancer mRNA vaccine.

Pro-tumorigenic Roles and Mechanistic Studies of Mixed Lineage Kinase Domain-like (MLKL) Protein in Cancers and the Development of Novel Therapeutic Strategy Targeting MLKL and Its-associated Pathways

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 65%

Abstract:

Little is known about the roles of mixed lineage kinase domain-like (MLKL) and necroptosis in tumorigenesis, progression, and therapeutic resistance. Here, we investigate the roles and underlying mechanisms of MLKL and necroptosis in cancers involved in tumor development and progression, immunosuppression, and therapeutic resistance. *In vitro* studies have indicated that MLKL may contribute to cholangiocarcinoma (CCA) growth and progression. Furthermore, high MLKL expression was associated with increased infiltration of M2 macrophages in CCA patients. The conditioned medium obtained from CCA MLKL knockdown cells induced M1 macrophage polarization, suggesting a potential role for MLKL in modulating M1/M2 macrophage polarization. Additionally, MLKL knockdown colorectal cancer (CRC) cells exhibited increased sensitivity to 5-fluorouracil treatment, potentially mediated by delayed TNFR-I (TNF-α receptor) endosomal trafficking. Finally, studies in NSCLC lung cancer patients suggest that MLKL and its interacting partner, RIPK3, may contribute to NSCLC prognosis and PD1/PD-L1 immune checkpoint inhibitor (ICI) responses.

Rationales/Problem statements:

Recent studies have shown that mixed lineage kinase domain-like (MLKL) and necroptosis may contribute to tumorigenesis, progression, and therapeutic resistance. Here, we investigate the roles and the underlying mechanisms of MLKL and necroptosis in cancers involved in tumor development and progression, immunosuppression, and therapeutic resistance. This research will focus on CCA, CRC and NSCLC. Tumor microenvironment (TME) of these cancers is associated with chronic inflammation and immunosuppression which contribute to cancer development, progression, and therapeutic resistance. Based on the literature reviews and our preliminary data, we have formulated the following hypotheses 1) MLKL expression is upregulated through pro-inflammatory interferons/Stat1/IRF1 signaling and epigenetic modifications 2) Upregulation of MLKL in cancer cells plays key

roles in sustaining tumor growth and progression, immunosuppression, and mediating therapeutic resistance including chemotherapy and immune checkpoint inhibitors (ICIs) which contribute to a shorter survival 3) MLKL promotes pro-tumorigenic signals in cancer cells potentially mediated through tumor-derived exosomes (TEXs).

Objectives:

1. To validate MLKL expression, its association with immune cells and prognosis in Thai CCA cohorts and response to ICIs in lung cancer patients.
2. To study the role of MLKL in promoting cancer growth and progression, immunosuppression, and chemotherapy resistance (*in vitro* models).
3. To validate the role of MLKL in promoting tumor growth in an animal model
4. To investigate the mechanisms of MLKL in CCA growth and progression and the CRC response to 5-fluorouracil.
5. To investigate regulatory mechanisms controlling MLKL expression
6. To develop a novel therapeutic strategy targeting MLKL that focuses on improving chemotherapy sensitivity

Progress/Findings/Results:

Regarding the pro-tumorigenic role of MLKL, using an MLKL knockdown cell model, we observed that MLKL promotes proliferation, invasion, and epithelial-mesenchymal transition (EMT) in CCA cells. These results suggest that MLKL might contribute to tumor growth and progression. To study the mechanisms through which MLKL promotes tumor growth and progression, we conducted RNA sequencing analysis in MLKL knockdown and control CCA cells; however, the data remains inconclusive. Further investigations may involve performing RNA sequencing or proteomic analysis in TNF-α-treated CCA cells. We are also exploring the role of MLKL in promoting tumor growth using a xenograft mouse model. In addition to the proposed work, we conducted bioinformatics analysis, examining the correlation between MLKL and pro-tumorigenic processes, including proliferation, invasion, and EMT gene signatures, in two additional RNA sequencing cohorts from the GEO dataset.

Furthermore, we analyzed the association between MLKL expression and tumor-associated macrophages (M2, CD163+ TAMs) in Thai CCA patients and found that high MLKL expression was associated with increased infiltration of M2 macrophages in CCA patients. In our *in vitro* models, we generated human monocyte-derived macrophages and differentiated them into M0, M1, and M2 phenotypes. We then obtained conditioned medium (CM) from MLKL knockdown and control cells and added it to M0 macrophages. Interestingly, we observed that CM from MLKL knockdown cells induced M0 to M1 macrophage polarization, with only a minor effect on M2 macrophage polarization. These findings suggest a potential role for MLKL in modulating M1/M2 macrophage polarization, which warrants further mechanistic studies.

Moreover, through comprehensive bioinformatics analysis in CRC patients and immunohistochemical staining in CCA tissues, we uncovered a significant correlation between high MLKL expression and poor therapeutic outcomes. We investigated the role of MLKL in chemotherapy responses in CRC cells and found that MLKL knockdown in CRC cells increased their sensitivity to 5-fluorouracil (5-FU) treatment. Mechanistic studies revealed an increase in the expression of p-p65, a marker of NF-kB activation, accompanied by TNF-α secretion following 5-FU treatment. The secretion of TNF-α after 5-FU treatment did not change in MLKL knockdown and control cells. However, we observed the localization of TNFR-I (TNF-α receptor) in early endosomes, leading to delayed receptor degradation, enhanced DISC formation, and potentiated apoptosis in MLKL knockdown CRC cells. These results suggest that depleting MLKL can enhance TNF-α-induced

apoptosis by modulating the endosomal trafficking of TNFR-I.

In addition, studies in non-small cell lung cancer (NSCLC) patients have demonstrated the prognostic and therapeutic significance of MLKL and its interacting partner, RIPK3. We obtained surgically resected samples from NSCLC patients and found that RIPK3 was negatively correlated with CD8+ T cells, while MLKL positively correlated with CD163+ M2 macrophages, suggesting the possible involvement of RIPK3 and MLKL in shaping an immunosuppressive microenvironment. More importantly, high RIPK3 status tended to be associated with clinical resistance to ICI therapy (*P*-value = 0.057). Therefore, RIPK3 emerged as a favorable prognostic factor in NSCLC patients, and both RIPK3 and MLKL could contribute to an immunosuppressive microenvironment, resulting in a low response to ICI therapy in NSCLC.

Conclusion:

In vitro studies have indicated that MLKL may contribute to CCA growth and progression. Furthermore, high expression of MLKL was associated with increased infiltration of M2 macrophages in CCA patients. The conditioned medium obtained from CCA MLKL knockdown cells induced M1 macrophage polarization, suggesting a potential role for MLKL in modulating M1/M2 macrophage polarization. Additionally, MLKL knockdown CRC cells exhibited increased sensitivity to 5-fluorouracil treatment, potentially mediated through the delay in TNFR-I endosomal trafficking. Finally, studies in NSCLC patients suggest that MLKL and RIPK3 may be involved in NSCLC prognosis and could contribute to immune checkpoint inhibitor (ICI) responses.

Current Output:

1. Duangthim N, Lomphithak T, Saito-Koyama R, Miki Y, Inoue C, Sato I, Miyauchi E, Abe J, Sasano S, Jitkaew S. Key necroptotic proteins RIPK3, MLKL and phosphorylated MLKL: Prognostic significance and Response to immune checkpoint inhibitors in non-small cell lung cancer. (Submitted)
2. Duangthim N, Sonkaew S, Tohtong R, Sawanyawisuth K, Jitkaew S. MLKL promotes tumor growth and progression and predicts a poor prognosis in cholangiocarcinoma. (Manuscript in preparation)
3. Sonkaew S, Duangthim N, Jitkaew S. Depletion of MLKL augments chemotherapy-induced apoptosis in colorectal cancer through delaying TNFR endosomal trafficking. (Manuscript in preparation)
4. Lomphithak T, Duangthim N, Sasano H, Jitkaew S. Tumor necroptosis-driven T cell activation promotes IL-6/Stat3-mediated PD-L1 upregulation and enhances PD-1/PD-L1 blockade in cholangiocarcinoma. (Manuscript in preparation)

Challenges/Problems and Possible solutions:

Most of the research plan has been carried out as proposed, and the experimental results are in line with our expectations. However, some aspects of the plan have taken longer than expected: such as 1) The investigation of MLKL's role in immunosuppression in human PBMCs was delayed due to the need for ethical approval. 2) The validation of MLKL in an animal model has been delayed as we are waiting for the Chulalongkorn animal facility to breed NSG mice. 3) Manuscript publication is delayed as we aim for a high-quality journal, necessitating mechanistic and animal studies.

Future plan:

We are continuing with ongoing experiments, which include validating MLKL's role in tumor growth in an animal model and conducting mechanistic studies to explore MLKL's potential roles in shaping M1/M2 macrophage polarization, potentially through MLKL-mediated exosome generation. Additionally, we will pursue the proposed aims in the 3rd year, which include: 1) Investigating the regulatory mechanisms controlling MLKL expression,

specifically through pro-inflammatory interferons/Stat1/IRF1 signaling and 2) Developing a novel therapeutic strategy targeting MLKL to enhance chemotherapy sensitivity, specifically by using the CRISPR/dCas9 system for transcriptional suppression of MLKL expression in combination with lower doses of 5-fluorouracil treatment.

Development of CpG-coated iron oxide nanoparticles as a cancer immunotherapy treatment for metastatic brain cancer

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Project duration: 2.5 year, from 01/11/2021 to 30/04/2024

Current progress: 78.5%

Abstract: Despite substantial challenges in cancer treatment, immunotherapy offers promising possibilities, particularly through repolarizing pro-tumor M2 macrophages into anti-tumor M1 macrophages. We developed novel nanocomposites, including dextran-coated magnetic nanoparticles with CpG or resiquimod, and lipid-based nanoparticles containing resiquimod. These were characterized by dynamic light scattering, XRD, UV-Vis, and ICP-OES. These nanocomposites not only reprogrammed M2 macrophages into M1 but also triggered cancer cell death via ROS generation, ferroptosis, or apoptosis. This, combined with M2 repolarization, significantly enhanced antiproliferation in transwell assays. Notably, the nanoparticles penetrated a simulated blood-brain barrier model and were internalized by glioblastoma cells, suggesting potential for brain tumor treatment.

Rationales/Problem statements:
Brain metastases are developed from the cancer cells which metastasize from primary tumors and enter brain microenvironments. Approximately, 20% of patients with cancer, especially patients with breast, lung, melanoma, renal and colorectal cancer will develop brain metastases, leading to a poor quality of life. Treating brain metastases faces a major challenge, causing ineffective treatment. Most of therapeutic agents could not pass through blood brain barrier (BBB). In addition, there are a limited number of immune cells in the brain environment and predominant cells are macrophages that promote tumor growth. Therefore, we are interested in developing a new brain-metastasis treatment thereby designing the nanomaterials which can not only pass through the BBB but also possess the capability in reeducating pro-tumor into anti-tumor macrophages.

Objectives:
Dextran-coated magnetic nanoparticles conjugated with CpG or loaded with resiquimod offer a promising approach for brain tumor therapy. These nanoparticles can effectively repolarize protumor (M2) macrophages into antitumor (M1) macrophages and successfully penetrate an *in vitro* blood-brain barrier model. Macrophages treated with these nanoparticles can trigger apoptosis in metastatic cancer cells, indicating potential for targeted brain tumor treatment.

Progress/Findings/Results:

We successfully synthesized a variety of nanomaterials including dextran coated-magnetic (MD) loading with resiquimod (MDR), MD conjugated CpG, and lipid nanoparticles loading with resiquimod (LNP-resiquimod). These nanomaterials were characterized using zetasizer, electron microscopy, Fourier-transform infrared spectroscopy, x-ray powder diffraction, and inductively coupled plasma - optical emission spectrometry (ICP-OES).

The fabricated nanocomposites demonstrated the ability to reprogram pro-tumor M2 macrophages into into anti-tumor M1. This conversion was validated by the upregulation of the M1 marker CD80 and suppression of the M2 marker CD206 after treated with nanocomposites. Then, the effect of polarized macrophages induced by the nanoparticles on the metastatic cancer (MDA-MB-231) was then systemically investigated. To evaluate the effect of these polarized macrophages on metastatic cancer (MDA-MB-231), we established a co-culturing model in a transwell system. LNP-resiquimod exhibited the ability to significantly reduce cell viability through the combined effect of repolarized M2 macrophages' pro-inflammatory cytokines.

Furthermore, we established a robust and reliable BBB model in a transwell system, confirmed by transepithelial electrical resistance measurements (TEER). Capability of the nanoparticles in crossing BBB model was also revealed. *In vitro* cytotoxicity studies revealed that these drug-loaded nanoparticles efficiently decreased the viability of glioma cells in both 2D and 3D models. Additionally, the magnetic nanocomposites exhibited a direct cytotoxic effect on MDA-MB-231 cells through ROS-mediated generation and ferroptosis pathways.

Conclusion: Our study successfully fabricated various nanomaterials, including MDR, MD-CpG, and LNP-resiquimod, demonstrating their remarkable potential for brain cancer therapy. These nanosystems have the ability to reprogram pro-tumor macrophages into anti-tumor macrophages. The repolarized M2 induced by nanoparticles had the ability to decrease cancer cell proliferation due to the released pro-inflammatory cytokines. Notably, the synthesized nanoparticles not only exhibited direct cytotoxic effects on cancer cells through diverse pathways like ROS generation and ferroptosis but also possessed the remarkable ability to cross the blood-brain barrier. Furthermore, they effectively inhibit the growth of brain cancer cells in 3D spheroid models, mimicking their tumor microenvironment. Therefore, we have successfully established nanoparticles-based therapeutic systems for brain cancer treatment.

Current Output:

- *Laboratory Prototypes*: 3 prototypes (magnetic nanocomposites loading with resiquimod or conjugating with CpG, lipid nanoparticles loading resiquimod)
- *Publications*: 1 published paper (Quartile 1)
- *International conference*: 1 poster presentation at ESB2023 conference and 2 accepted poster presentation at ICONAN 2024

Challenges/Problems and Possible solutions:

Future plan:

Animal experiments are planned for 2024, subject to final ethical and regulatory approvals.

Development and Expansion of Innovative Theragenerative Biomaterials (THAiBioGels) and Medical Devices for Enhancing Bone Tissue Regeneration: From Blench and Pilot Animal Before Clinical Translation

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Project duration: 3 year, from 1 November 2022 to 31 October 2024

Current progress: 60%

Abstract:

Organic-inorganic composite scaffolds are of interest for bone tissue engineering and post injury-bone regeneration. In the present study, aimed to investigate the suitability of the trace element-incorporated hydroxyapatite (THA) integrated bioactive gel (BioGel) (star-shaped polycaprolactone (starPCL)/Chitosan (Chit)) (THAiBioGel) composite scaffold which was fabricated using melt/solution blending method as a bone scaffold. The results revealed that the as-prepared THAiBioGel demonstrated that THA was successfully incorporated into BioGel and yield a desirable porous structure with mechanical strength of 10.35±0.27 MPa, 13.62±0.32 MPa and 18.30±0.54 MPa for weight ratio of THA:BioGel 5:5, 7:3 and 9:1, respectively. Furthermore, the *in vitro* biological assay confirmed that the present material was not only good for osteoblast-like UMR-106 cell attachment on its surface, but also significantly promoted bone formation as demonstrated by an increase in alkaline phosphatase (ALP) activity. Our data, therefore, strongly suggested that THAiBioGel could be used as scaffold for bone tissue engineering.

Rationales/Problem statements:

Although the repair of bone defects has continuously attracted the attention of researchers in both medical engineering and material science, it still poses a big challenge. Modified hydroxyapatite (HAP) with ions doping ($Ca_{10-\delta}M_{\delta}(PO_4)_{5.5}(CO_3)_{0.5}(OH)_2$, M = trace elements) and their composites have shown considerable potential due to their excellent osteoconductivity, osteoinductivity and biodegradability. Besides, these ions are the main mineral elements in bone and are essential for various biological processes leading to biomineralization and bone growth. From our knowledge, a single material does not fulfill all requirements for bone tissue applications. Thus, a number of investigators have developed composite materials based on calcium phosphate (CaP) and polymers.

Objectives:

In this study, the combination of StarPCL, chitosan and the multi-trace element (Mg, Fe, Zn, Mn, Cu, Ni, Mo, Sr, Co, B and CO_3^{2-}) incorporated hydroxyapatite (THA) ($Ca_{10-\delta}M_{\delta}(PO_4)_{5.5}(CO_3)_{0.5}(OH)_2$, M = trace elements) was synthesized. For suggested that THAiBioGel could be used as scaffold for bone tissue engineering, the pilot study based on compatible mechanical strength, desirable bone cell affinity and *in vitro* ALP activity upon contact with the synthesized scaffolds were studied.

Progress/Findings/Results:

The morphology of the THAiBioGel scaffold revealed a porous structure with pore size between 50-150 μm and the porosity of the as-obtained THAiBioGel composite scaffolds gradually decreases with the increase of THA in the range of 46%-70% as measured by the ethanol displacement method. Notably, it was also observed that some pores slightly collapsed with the increase in ratio of THA up to 9:1 by weight ratio, which was mainly due to the breakage of continuous organic BioGel phase caused by THA incorporation. The compressive strength from the stress-strain curve were 10.35±0.27 MPa, 13.62±0.32 MPa and 18.30±0.54 MPa for weight ratio of THA:BioGel 5:5, 7:3 and 9:1, respectively. Normally, the compressive strength and modulus of natural cancellous bone were within 2-20 MPa and 0.1-2 GPa, while those of cortical bone were within 100-200 MPa and 15-20 GPa. Based on this observation, the THAiBioGel composite scaffold possessed a compatible compressive strength and modulus with the natural cancellous bone rather than cortical bone. For *in vitro* evaluation, the morphology of cell adhesion on glass (control) and THAiBioGel91 composite scaffold at day 3, 5, and 7. The THAiBioGel91 scaffold showed good biocompatibility with excellent cell adhesion. According to the present results, there were no differences in osteoblast proliferation on THAiBioGel91 and glass (positive control substrate) after 7 days of culture. The ALP activity of osteoblast-like UMR-106 cells cultured on THAiBioGel91 sample compared with glass as control after 3, 5, and 7 days. ALP is an osteoblast-specific enzyme produced during osteogenesis and is widely used to represent the early stage of cell differentiation. Our results showed that, the levels of ALP activity in the THAiBioGel91 group on day 3 and 5 were apparently lower than that of control, but later caught up and was not different from control on day 7. This increased ALP activity of osteoblasts could have been induced by either the microstructure of the scaffolds or the dissolution of ions, e.g., Mg^{2+}, Sr^{2+}, Zn^{2+}, Fe^{2+} from the scaffolds which had been previously shown both *in vitro* and *in vivo* stimulate cell proliferation and differentiation.

Conclusion:

In this study, we reported on the fabrication and characterization of THAiBioGel with the physicochemical properties and biological assay based on cell adhesion and ALP activity for bone tissue engineering. The successful composite scaffold with THA:BioGel at 9:1 weight ratio showed a mechanical strength within natural cancellous bone. Also, the in vitro test (cell adhesion and ALP activity), confirmed better osteoblast attachment and growth on the THAiBioGel surface. This preliminary study revealed that this formulation of THAiBioGels had a potential to the developed into bone composite scaffold with suitable properties for practical applications.

Current Output: 7 publications/ 1 EMF lab scale medical device/ 1 THA and THAiBioGels prototype

Challenges/Problems and Possible solutions:

The research is in progress.

Future plan:

The *in vivo* bone formation after THAiBioGels implant needs to be confirmed by further experiments, which is the direction of our future research.

Construction of Tissue-Engineered Cartilage from Chondrocytes and Mesenchymal Stem Cells Derived from Synovial Tissue and Synovial Fluid for the Treatment of Osteoarthritis

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 35%

Abstract:
In recent years, regenerative medicine, particularly tissue engineering, has gained much attention as an innovative therapeutic option. Our research group has developed a scaffold-free technology for constructing tissue-engineered cartilage, employing either human primary chondrocytes or differentiated chondrogenic stem cells to treat cartilage defects. Nevertheless, the persistent challenges lie in creating thicker tissue constructs, primarily due to limited oxygen and nutrient diffusion. Therefore, a novel approach to enhance the mechanical integrity of thicker tissue-engineered constructs, while preserving their high biological functionalities, is needed.
In this study, we proposed a new tissue fabrication method that combines cell sheet technology with cell pellets. This approach yielded substantially thicker cartilage tissues with upregulated collagen type II expression, indicating high quality cartilage formation. In addition, we explored the potential of synovial-derived mesenchymal stem cells as an alternative cell source for chondrogenesis. Ultimately, our research aims to incorporate both human primary chondrocytes and synovial-derived mesenchymal stem cells in the construction of tissue-engineered cartilage for regenerative medicine applications.

Rationales/Problem statements:
Thailand's transition into an aging society has led to an escalating array of age-related health issues, including cartilage defects and osteoarthritis. In response, cell-based therapy has emerged as a promising therapeutic option for regenerating and repairing damaged tissues. Cell sheet technology offers the potential to fabricate tissue-engineered products without relying on scaffolds by stacking multiple cell sheets to create a 3-dimensional construct. However, a significant challenge lies in creating thicker tissues as a large number of cell sheets are needed. Unfortunately, this can lead to the undesirable issue of cell sheet delamination, resulting in construct failure.
Furthermore, the procurement of human primary chondrocytes requires surgical procedure, posing potential risks to patients. Hence, alternative cell sources are desirable. Mesenchymal stem cells (MSCs) have become promising candidates for regenerative therapies, owing to their ability to be isolated from various tissues and differentiated into different cell types. Interestingly, synovial membrane and fluid have exhibited the presence of MSCs with chondrogenic differentiation ability. However, the potential of synovial tissue as a cell source remains largely unexplored, presenting a readily accessible option, particularly in osteoarthritis patients. Investigating their suitability as a cell source holds great promise for advancing the field of cartilage tissue engineering.

Objectives:

- To develop a protocol for isolating and culturing MSCs harvested from synovial tissue and synovial fluid, with a focus on evaluating their stem cells properties
- To develop a method to fabricate tissue-engineered cartilage by integrating cell sheet technology with cell pellets. The biological functionalities and mechanical attributes of these tissue constructs are characterized.
- To study the underlying regenerative mechanisms of these cartilage tissues constructed using both human primary chondrocytes and synovial-derived MSCs.

Progress/Findings/Results:

Part 1: Initially, layering multiple chondrocyte pellets on a tissue culture dish resulted in the tissue disintegration. Chondrocyte cells in the pellets were unable to migrate out and fusing with neighboring pellets. It is possible that high extracellular matrix proteins in the pellet culture prevented chondrocyte cell migration. Consequently, individual pellet failed to coalesce into a larger unified tissue structure. To overcome this problem, chondrocyte pellets were layered onto a chondrocyte cell sheet, serving as a support for the pellets. The pellets attached firmly to the cell sheets, and chondrocytes in the cell sheets migrated outward, effectively binding the pellets to form an intact tissue construct. After 7 days of incubation, chondrocyte pellet-sheet tissues spontaneously detached from the surface, yielding a construct measuring 5 mm in diameter and 1 mm in thickness.

Part 2: Approximately 4 x 10^6 MSCs/gram were successfully isolated from synovial tissue, while synovial fluid yielded no harvestable MSCs. Only about 20% of MSCs from the synovial tissue sample were attached to the surface and proliferated. Nevertheless, these cells exhibited MSC characteristics, as positively confirmed by the cell surface markers and a tri-lineage differentiation profile. Upon induction of chondrogenic differentiation, the synovial-derived MSCs demonstrated high expression levels of collagen type II and aggrecan, indicating their potential use in cartilage tissue engineering.

Conclusion:

Our study demonstrated the successful construction of thicker tissue-engineered cartilage through a novel approach, combining chondrocyte cell sheets and pellets. Synovial membrane-derived MSCs exhibited crucial stem cell characteristics and displayed a high chondrogenic potential. These findings emphasize the promise of utilizing primary chondrocytes and synovial membrane-derived MSCs in the development of advanced cartilage tissue engineering strategies.

Current Output: Chondrocyte pellet-sheet tissue prototype

Challenges/Problems and Possible solutions:

Future plan:

The characterization of tissue-engineered cartilage from primary chondrocytes will be performed using immunohistochemistry and Atomic Force Microscopy. Synovial-derived MSCs will be used to construct 3D cartilage constructs, which will be evaluated as a potential alternative for cartilage treatment. Finally, an innovative approach will be explored, involving the construction and characterization of tissue-engineered cartilage using both chondrocytes and synovial-derived MSCs.

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Aquaculture, Biotechnology)

Enzyme Engineering for Development of New Detection Technology:
Luciferin Synthesis and Pesticide Detection by Luminescence Enzymatic Cascades

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 80%

Abstract:

D-Luciferin (D-LH_2), a substrate of firefly luciferase (Fluc), is important for a wide range of bioluminescence applications. This work reports a new and green method using enzymatic reactions (HELP, HadA Enzyme for Luciferin Preparation) for synthesizing D-LH_2. The method is powerful as it can synthesize 12 D-LH_2 derivatives with 4 novel D-LH_2 analogues with 51% yield. The biocatalytic HELP reaction is simple, environmentally friendly, and currently scalable to 100 mg/12 h. The 5'-MeLH_2 gives brighter and more steady light with longer wavelengths than the native D-LH_2. As precursors for the synthesis of D-LH_2 analogues are toxicants derived from pesticides and herbicides, the HELP reaction is also attractive for a toxicant circular economy in which industrial waste (i.e., pesticides) can be converted into valuable products (i.e., D-LH_2 analogues), illustrating a new mode of bioremediation technology. Using HELP, we further developed LUMOS (Luminescence Measurement of Organophosphate and Derivatives) technology for *in situ* detection of organophosphate pesticides (OPs) and organochlorine including parathion, methyl parathion, EPN, profenofos, and fenitrothion, chlorpyrifos, triclopyr, 3,5,6-trichloro-2-pyridinol and 3,5,6-trichloro-2-pyridinol by coupling the reactions of OPs hydrolase and Fluc. The LUMOS technology can detect these OPs at parts per trillion (ppt) levels. The method can directly detect OPs in food and biological samples without requiring sample pretreatment.

Rationales/Problem statements:

Bioluminescence or light emission catalyzed by luciferases is a powerful analytical method for biomedical research as well as for the detection of toxicants in food and the environment. About 30% of high throughput screening (HTS) experiments employ bioluminescence detection. Although various types of luciferases exist, firefly luciferase (Fluc), which uses D-Luciferin (D-LH_2) as a substrate, remains one of the most utilized systems due to its high quantum yield, resulting in bright light with a maximum emission (λ_{max}) at ~ 560 nm. Modification of D-LH_2 to obtain its analogues with brighter and longer wavelength light emission (> 600 nm) is key for innovation development to expand and enhance the usage of D-LH_2 for wider applications. Brighter and longer wavelength light can penetrate through cells and tissue compartments efficiently, facilitating real-time bioluminescence imaging in cell lines and animal models.

Objectives:

1. To engineer flavin-dependent dehalogenase (HadA) for the synthesis of new luciferins.
2. To enhance the efficiency of Fluc by engineering it for improved utilization of the newly synthesized luciferin as a substrate.
3. To modify flavin reductase (C_1) for pesticide detection.
4. To establish a prototype reaction for the effective detection and degradation of pesticides.

Progress/Findings/Results:

1. **Synthesizing D-luciferin analogues from phenolic and benzoquinone compounds**

HadA Enzyme for Luciferin Preparation (HELP) reactions can use 19 phenolic derivatives to synthesize 8 D-LH_2 analogues including halogenated D-LH_2, amino D-LH_2, and methyl D-LH_2. Importantly, 5'-MeLH_2, 4',5'-DiMeLH_2 are novel compounds. The HELP reaction is a useful synthesis toolbox for the preparation of D-LH_2 analogues under mild conditions by simply adding relevant enzymes and D-Cys into aqueous solutions.

Currently, we have obtained three novel red-shifted D-LH_2 analogues: 5',7'-DiMeLH_2, 5',7'-DiOMeLH_2, and 7'-MeNpLH_2.

2. **Bioluminescence characteristics of D-LH_2 analogues**

To verify that the compounds synthesized by the HELP reaction are indeed luciferins, which can react with ATP and oxygen in the reaction catalyzed by *Photinus pyralis* luciferase (Fluc) to emit light, the Fluc reactions with D-LH_2 analogues were carried out to investigate emission patterns, light stability, steady-state kinetics parameters and pH effects on bioluminescence. The results indicate that all D-LH_2 analogues serve as substrates for Fluc. The reactions emit light with maximum wavelengths around 560-620 nm. Importantly, three compounds give red-shifted bioluminescence with λ_{max} values greater than 600 nm, significantly different in characteristics from the natural D-LH_2. These compounds showed light emission kinetics similar to the native D-LH_2.

3. **Detection of OPs and Their Metabolites by LUMOS Technology**

Organophosphates and organochlorine including parathion, methyl parathion, EPN, profenofos, and fenitrothion, chlorpyrifos, triclopyr, 3,5,6-trichloro-2-pyridinol and 3,5,6-trichloro-2-pyridinol can be converted into D-LH_2 analogues with different colors. The LUMOS reaction thus can generate signals specific to the individual compounds.

4. **Detection of OPs in Fruit Samples by LUMOS Bioluminescence in Comparison with HPLC/MS**

As the sensitivity of LUMOS bioluminescence should allow direct detection of pesticide contaminants in real food samples, we thus explored the use of LUMOS for detection of five OPs (parathion, methyl parathion, EPN, profenofos, and fenitrothion) in common fruits (*viz* apple, banana, and guava) in comparison with the HPLC/MS method. The overall workflow of using LUMOS for detection of OPs in fruits including extraction, biodegradation-luciferin synthesis, and biodetection. The results showed that our extraction method could recover OPs from apple, banana, and guava at around 20-100 % recovery, depending on the solubility of the OPs species. The analysis indicated that LUMOS has greater sensitivity than HPLC/MS for detection of all the OPs tested, at a range of ppt levels. The limit of detection using LUMOS was lower than the maximum residue limits (MRL) of each OPs marked as high risk, indicating that LUMOS can be used as a sensitive tool for food safety testing. LUMOS is thus applicable for future development as a point-of-care device for the detection of toxicants in food and biological samples.

Conclusion:

This work established the *de novo* synthesis of D-LH_2 analogues from phenolic and benzoquinone compounds using HELP reaction. The method is powerful as it can synthesize 12 D-LH_2 derivatives with 4 novel D-LH_2 analogues with 51% yield. The biocatalytic HELP reaction is simple, environmentally friendly, and currently scalable to 100 mg/12 h. The 5'-$MeLH_2$ gives brighter and more steady light with longer wavelengths than the native D-LH_2. As precursors for the synthesis of D-LH_2 analogues are toxicants derived from pesticides and herbicide, the HELP reaction is also attractive for a toxicant circular economy in which industrial waste (i.e., pesticides) can be converted into valuable products (i.e., D-LH_2 analogues), illustrating a new mode of bioremediation technology.

LUMOS technology shows high sensitivity that can detect nine pesticides and metabolites in real samples at ppt level. LUMOS is thus applicable for future development as a point-of-care device for the detection of toxicants in food and biological samples.

Current Output: 15 publications, 5 patents, 4 prototypes

Challenges/Problems and Possible solutions: -

Future plan:

1. Expansion of other enzymatic systems for pesticide detection.
2. Expansion of pesticide detection scope.
3. Increase sensitivity of detection.
4. Evaluate the pesticide detection compared to standard methods.

Multi-omics Investigation of Molecular Mechanisms Underlying Adaptive Response and Tolerance to Heat Stress and Ethanol Fermentation-associated Stresses in Thermotolerant *Saccharomyces cerevisiae* Strains

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Project duration: 2.5 year, from 01 November 2021 to 30 April 2024
Current progress: 70%

Abstract:

Previously, the *Saccharomyces cerevisiae* C3253 and C3751 strains have been shown to be highly resistant to multiple fermentation stresses and exhibit excellent fermentation performances. In this study, we aimed to elucidate cellular mechanisms underlying multiple stress tolerance in these strains by using multi-omics approaches. Complete genome sequencing and analysis were performed and showed that the genomes of our strains contain some specific genes, probably involved in stress tolerance. The transcriptomic analysis revealed that, in response to high temperature, the up-regulated transcripts in the tolerant strains were enriched in the cell cycle group, while the down-regulated transcripts were enriched in the TCA pathway group. The metabolomic data showed that the predominant pathways of the tolerant strains were related to glycerophospholipid and amino acid metabolisms. Based on these findings, several novel mechanisms involved in tolerances to fermentation-associated stresses have been identified, which are important for strain improvement for industrial applications.

Rationales/Problem statements:

The demand for eco-friendly renewable fuels, especially bioethanol, has increased in recent years. The yeast *Saccharomyces cerevisiae* is commonly used in industrial ethanol production due to its high efficiency in ethanol fermentation. Recently, ethanol fermentation at high temperatures has gained increasing interest due to its benefits of saving cooling costs and preventing bacterial contamination. During fermentation, yeast cells encounter several stresses including osmotic, ethanol, and oxidative stresses. To achieve efficient high-temperature ethanol fermentation, a yeast strain with high tolerances to not only heat stress but also other fermentation-associated stresses is therefore indispensable. Previously, we found that the *S. cerevisiae* C3253 and C3751 strains were resistant to multiple fermentation stresses and showed better fermentation performances than the industrial strain (TISTR5606).

Objectives:

1. To elucidate cellular mechanisms underlying multiple stress tolerance in these strains by using multi-omics approaches.

Progress/Findings/Results:

Genomic analysis. The complete genome sequencing and analysis of three *S. cerevisiae* strains, i.e., C3751 (thermotolerant strain), C3253 (multiple-stress tolerant strain), and BY4743 (laboratory control strain), were performed. The genomic features showed that all genomes were approximately equivalent in size (approximately 12 Mbp). Although the number of predicted genes of our strains was lower than that of the reference genome S288C, the orthologous analysis showed a relatively comparable number of gene clusters (5,168–5,191 clusters). Interestingly, some specific genes were detected only in the genomes of C3253 and C3751; including *KHR1* encoding a heat-resistant killer toxin, and *MPR1* encoding a L-azetidine-2-carboxylic acid acetyltransferase.

Transcriptomic analysis. Transcriptomic analysis of heat stress response in the C3751 and C3253 strains revealed that overall transcriptomic changes were more apparent after prolonged exposure (12 h), as compared to early exposure (30 min). Under high-temperature conditions, the up-regulated transcripts in the tolerant strains were enriched in the functional group for the cell cycle, while the down-regulated transcripts were enriched in the group related to the TCA pathway.

Metabolomic analysis. Based on the obtained metabolomic profiles, significant differences were detected between metabolome data derived from samples incubated at 30 °C and 40 °C for 12 h. In addition, the tolerant stains displayed different metabolomes as compared to the control strain. The predominant pathways of the tolerant strains were those related to glycerophospholipid and amino acid metabolisms. Furthermore, the metabolomic profiles of the C3253 strain showed that the major metabolites accumulated during fermentation at high temperatures were those of the pentose phosphate pathway (PPP), particularly NADPH. Supporting these findings, the expression of genes involved in NADPH biosynthesis and the activities of NADPH-generating enzymes were up-regulated in response to high-temperature fermentation.

Conclusion:

- The genomes of our strains contain specific genes, probably involved in stress tolerance.
- In response to high temperature, the up-regulated transcripts in the tolerant strains were enriched in the functional group for the cell cycle.
- The predominant metabolomes of the tolerant strains were related to glycerophospholipid, amino acid metabolisms, and pentose phosphate pathway.

Current Output: 4 manuscripts in preparation.

Challenges/Problems and Possible solutions: -

Future plan:

- To elucidate the molecular mechanisms of the candidate proteins and metabolites in tolerances against stresses related to high-temperature fermentation

Development of laboratory diagnosis of tuberculosis in cynomolgus macaques, incidence, association of gut microbiomes and whole genome sequences of *Macaca fascicularis* and *Mycobacterium tuberculosis* (B05F640122)

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Project duration: 3 years, from 01/November/2021 to 31/October/2024
Current progress: 50 %

Abstract:

Herein, we studied tuberculosis (TB), a deathly disease causes by *Mycobacterium tuberculosis* (*M.tb*) in both captive and wide cynomolgus macaques (*Macaca fascicularis*)in Thailand. The new algorithm in-house mIGRA is developed in order to use for rapid screening of latent TB infection (LTBI) and prevention of disease spreading. For active TB (ATB) we have showed that the molecular techniques like GeneXpert recommended by WHO for diagnosis of TB disease in human and in-house nested PCR are also useful for diagnosis of ATB in cynomolgus macaques (CM). The gut microbiomes in healthy, LTBI and ATB were explored and found significant differences between healthy and LTBI or healthy and ATB. About 20 populations of wide living CM in Thailand were screened forTB using in-house nested PCR and revealed that 5 populations were naïve for TB. The
study on whole genome sequences of CM and *M. tb* are continuing with all above studies.

Rationales/Problem statements:

Cynomolgus macaques (CM; *Macaca fascicularis*), commonly found in Thailand, is recently popular for using as an animal model specially in medical and pharmaceutical fields and TB-free is a strict condition that CM animal model must be. However, after exposure to a TB microbe, CM can be in either stage of latent-TB (asymptomatic) and
active-TB (symptomatic), like that presence in humans. A previous study reported that TB infection in captive CM was caused by *M. tuberculosis*. Therefore, early detection of TB infection in CMs is required. Herein, the protocols and new algorithm for TB detection in CMs are proposed. Meanwhile, the prevalence of TB infection in non-captive CMs has
been explored. In addition, the microbiome study is applied for helping in treatment.

Objectives:

1. To determine the TB incidence in wild cynomolgus macaques
2. To develop the TB diagnostic methods for captive and wild cynomolgus macaques
3. To investigate the mechanisms of infection and progression of TB in association with the genome of pathogens, host, and microbiome
4. To use the knowledge gained in this project for drug and vaccine development for the human use
5. To build the network and collaboration among researchers based on their unique expertise which should support the service and research on infectious diseases in cynomolgus macaques in Thailand

Progress/Findings/Results:

Project1 Development of methods to detect tuberculosis infection and study of *Mycobacterium tuberculosis* complex (MTBC) genetic diversities isolated frominfected cynomolgus macaques comparing to human MTBC isolates:

(1.1) Propose the steps of TB screening and a new algorithm for mIGRA interpretationfor TB infection in cynomolgus macaques in Year-2 and continue to validation of the mIGRA algorithm in Year-3

(1.2) Reveal the usefulness of GeneXpert for diagnosis of active TB in detection of DNA in oro-pharyngeal wash samples of CM

(1.3) Collection of 9 *M. tuberculosis* isolates from natural TB-infected CMs (captive) in Year-2 and will be used for WGS analysis in Year-3

(1.4) Propose a model in separating the ATB CM from the gang to prevent the spreadingof TB

Project2 Association between gut microbiome and *Mycobacterium tuberculosis* infection in cynomolgus macaques (*Macaca fascicularis*):

(2.1) Able to differentiate gut-microbes between TB-infected CM groups (latent-TB andactive-TB), compared to healthy

(2.2) Understand the difference in gut and pharyngeal-tracheal microbiome organisms correlated to TB infection in CMs

Project3 Epidemiology and susceptibility on tuberculosis in association with genetic characteristics in wild cynomolgus macaques:

(3.1) Determine the prevalence of TB infection (active stage) in 15 populations of wild cynomolgus and rhesus macaques, in total 524 individual, using IS*6110* nested-PCRmethod (modified from Githui et al., 1999). Ten out of 15 populations showed positive results (7-60%).

(3.2) Develop serological test (active and latent stage) method, namely Multi-antigen print immunoassay (MAPIA) which detected ESAT6 and CFP10 antibodies in 3 populations of wild cynomolgus macaques, in total 119 individuals. 47.1% of animals showed positive results.

(3.3) Develop non-invasive methods of specimen collection (rope-bait method for oral specimens and direct fecal swab for fecal specimens) and determined *Mycobacterium tuberculosis* complex (MTBC) using IS*6110* nested-PCR method. Six populations (510 individuals) of wild cynomolgus macaques were tested, and 5 of them showed positive results (3.6-12.5%).

(3.4) From the developed methods mentioned above, we could identify wild monkeys of naïve, latent, and active stage of TB exposure. Those monkeys will be determined their genetics (whole genome sequences (WGS) and SNPs) in Year-3.

(3.5) Conduct WGS of a Thai cynomolgus macaque and submitted to GenBank. This WGS will be used as a reference genome for genetic analysis of naïve, latent, and active TB macaques in Year-3.

Conclusion:

1. Steps of TB screening and a new (mIGRA) algorithm for TB interpretation were proposed. *M. tuberculosis* is the TB infectious agent, causing of death in captive CM. The detection of *M.tb* DNA using GeneXpert can be used for rapid diagnosis of TB in CM.
2. The gut microbiome information of cynomolgus macaques could be applied in advancefor setting the protocols how to conduct the husbandry conditions and foods for CMs.
3. We could develop diagnostic methods of MTBC infection, for both latent and activestages, in wild cynomolgus and rhesus macaques, and also develop non-invasive specimen collection methods.

Current Output:

Publications (4 papers):

1. Prevalence of *Mycobacterium tuberculosis* Complex among wild rhesus macaques and 2 subspecies of long-tailed macaques, Thailand, 2018–2022. *Emerging Infectious Diseases*. 2023. 29: 3 DOI: https://doi.org/10.3201/eid2903.221486 (IF2023 = 16.1; Q1)
2. Non-invasive specimen collections for *Mycobacterium tuberculosis* detection in free ranging long tailed macaques (*Macaca fascicularis*). PLoS ONE. 2023. 18(8): e0289961. https://doi.org/10.1371/journal.pone.0289961 (IF 2023 = 3.7; Q1)
3. Alteration of gut microbiota in wild-borne long-tailed macaques after 1-year being housed in hygienic captivity. Scientific Reports. 2023. 13:5842 https://doi.org/10.1038/s41598-023-33163-6 (IF 2023 = 4.996; Q1)
4. Influence of COVID-19 on the emergence of stone-tool use behavior in a population of common long-tailed macaques (*Macaca fascicularis fascicularis)* in Thailand. *American Journal of Primatology*. Accepted on Nov 18, 2023 (IF2023 = 3.014; Q1)

Poster presentation (2 presentations):

1. Development of in-house IGRA for tuberculosis diagnosis in cynomolgus macaques (*Macaca fascicularis*) by Dr. Saradee Warit
2. Application of Xpert MTB/RIF Ultra to diagnose active tuberculosis in cynomolgus macaques by Dr. Prapaporn Srilohasin

at National Primate Research Center of Thailand Chulalongkorn University Symposium2023 under the theme of "Roles of non-human primates on drug and vaccine developmentduring the COVID era" on 18th-19th February 2023, Mandarin Hotel (Samyan), Bangkok ***Oral***

Presentation (1 presentation):

Topic: Mitogen selection and the new mIGRA algorithm for TB detection in Thai captive cynomolgus macaques (CM) by Dr. Saradee Warit at the 40th Annual Symposium on Nonhuman Primate Models for AIDS on October 10-13, 2023 organized by California National Primate Research Center (CNPRC), University of California Davis, USA

Submitted papers (3 papers) :

1. New Gamma Interferon (gIFN) algorithm for Tuberculosis Diagnosis in Cynomolgus macaques. Frontiers of immunology (In progress)
2. Advancing Tuberculosis Diagnosis and Management in Cynomolgus Macaques: The Role of the Xpert MTB/RIF Ultra Assay. Scientific report (submitted)

Full-length 16S rDNA sequencing based on Oxford Nanopore Technologies revealed the association between gut-pharyngeal microbiota and tuberculosis in cynomolgus macaques (In progress)

Challenges/Problems and Possible solutions:

Since the animal subjects for this project are wild cynomolgus and rhesus macaques in Thailand, the survey of animals and specimen collections could not be done during the time of Covid-19. The solution was that the experiments were conducted mainly in the laboratory and monkey capturing and specimen collections were done after the restriction of Covid-19 was lifted.

Future plan:

1.Understanding of host genome in associated with TB susceptibility in CM.2.Algorithm of TB diagnosis in CM and management.

3.Understand the genetic diversities of *M.tb* isolated from CM comparing with human. 4.The microbiome study in gut and respiratory tract during TB progression from LTBI to ATB in CM and TB genotypes in non-captive CM (be continued in the next project)

5.An association between the host genome (WGS and SNPs) and TB infection stage (naïve,latent, and active) of Thai cynomolgus macaque will be analyzed.

Investigation and Characterization of Antimicrobial-resistant *Streptococcus suis* Strains Isolated from Pigs in Thailand

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 60%

Abstracts:

S. suis isolated from diseased pigs (44 isolates) during 2018-2020 and healthy slaughtered pigs (395 isolates) during 2022-2023 were characterized. Most diseased pig isolates were derived from lung tissues and serotype 2 or ½ emerged as the predominant serotype. *S. suis* isolates were collected from pig carcasses with the prevalence of 58.1%. Among healthy slaughtered pigs, serotype 19 was the most frequent, followed by serotype 2 or ½, 3, and 29, whereas 37.2% of the population were non-typable. Antimicrobial susceptibility test demonstrated multidrug resistance, compromising the effectiveness of ampicillin, cefepime, cefotaxime, ceftiofur, ceftriaxone, chloramphenicol, florfenicol, gentamicin, penicillin, and tiamulin. The *S. suis* genome analysis revealed a high genetic diversity with the highest prevalence sequence type of ST104 and the presence of 18 antimicrobial resistance genes associated with resistance against six different antibiotic groups and multiple amino acid alterations within penicillin-binding proteins (PBP1a, PBP2a, PBP2b, and PBP2x) related with beta-lactams non-susceptibility.

Rationales/Problem statements:

Antibiotics have long been used as therapeutic and/or prophylactic medication for zoonotic *S. suis* infection in agricultural and healthcare settings. However, the imprudent use of antibiotics contributing to emergence and widespread of antibiotic resistant *S. suis* becomes a significant challenge in many endemic countries, including Thailand. A large body of knowledge has shown the growing trend of antibiotic resistance (AMR) in streptococci worldwide; however, antimicrobial resistance profiles can be different depending on the geographical location, management of antibiotic prescription, and health condition (Segura et al., 2020). Limited data exists on the AMR status and resistance determinants of *S. suis* isolates in Thailand, an endemic area for *S. suis*. Consequently, there is a pressing need for a thorough investigation and characterization of the genetic determinants responsible for *S. suis* resistance in Thailand. Such efforts are crucial for effective AMR monitoring and preventing its spread in the region**.**

Objectives:

1. To obtain whole genome sequences of AMR *S. suis* isolated from pigs in Thailand.
2. To identify AMR determinants in *S. suis* isolates.
3. To understand linkages between AMR determinants and antibiotic susceptibility profiles of *S. suis* isolates.
4. To validate the transferability of mobile-genetic elements (MGEs) carrying AMR determinants.

Progress/Findings/Results:

A total of 44 *S. suis* isolated from diseased pigs between 2018 and 2020 (Lunha et al., 2022)

were selected for the study. They were derived from 28 farms localized in 6 provinces in Central Thailand. Most of them were isolated from lung tissues (82.2%). The most abundant were serotype 2 or ½ (26.7%), followed by serotype 8 and 29 (8.9% each), consistent with previously reported data that serotype 2 was the most pathogenic for both pigs and humans (Segura et al., 2020). A total of 395 isolates obtained from 275 out of 473 (58.1%) pig carcasses were confirmed as *S. suis*, indicating high carrier rates in pigs brought to slaughterhouses. Among the 395 *S. suis* isolates, 62.8%were classified into 22 serotypes, which serotype 19 (8.4%) was the most common, followed by serotype 2 or ½ (7.1%), 3 (6.3%), 8 (6.1%), 29 (5.8%), and 7 (5.1%), while 37.2% of isolates were classified as non-typeable. A previous study reported that serotype 23 (10.2%) was the most prevalent, followed by serotypes 9 (8.2%), 7 (8.2%), and 2 (5.6%) among *S. suis* isolates found in healthy pig in Northern Thailand (Thongkamkoon et al., 2017). Whereas a study from Central Thailand demonstrated that serotype 16 (11%) was the most frequent serotype recovered from healthy pigs, followed by serotypes 8 (7%), 9 (6%), and 3 (5%) (Meekhanon et al., 2017). This suggested that the distribution of *S. suis* serotypes might be geographically dependent. Antimicrobial susceptibility testing on 201 representative *S. suis* (44 and 157 isolates from diseased and healthy pigs, respectively) demonstrated multidrug resistance (MDR) phenotype with a notable trend of reducing susceptibility to common drug of choice, beta-lactams, including penicillin, ampicillin, amoxicillin/clavulanic acid, ceftriaxone, and cefotaxime. At this stage, the raw whole-genome sequencing (WGS) reads of 90 *S. suis* isolates was retrieved. The genome analysis revealed a high genetic diversity with the highest prevalence sequence type (ST) of ST104 and high number of isolates belonged to novel STs (74.4%). Numerous AMR genes were identified with the highest frequency of *ermB* (83.3%) and *tetO* (80.0%), and many located within mobile-genetic elements (MGEs). A high genetic diversity along the transpeptidase domain (TPD) of penicillin-binding protein (PBP1a, PBP2a, PBP2b, and PBP2x) was observed with the specific alteration related with beta-lactams non-susceptibility (Lunha et al., 2023).

Conclusion:

S. suis is prevalent in healthy slaughtered pigs, raising concerns about potential transmission to humans. The widespread presence of MDR *S. suis* strains indicates emerging of AMR issue in pig-isolated *S. suis* populations. The high frequency of AMR determinants, including MGEs-carrying AMR genes in pigs isolated *S. suis*, emphasizes the need for a food safety campaign and improved hygiene in livestock systems. Moreover, continuous monitoring of AMR in *S. suis*, focusing on prevalence and mechanisms, and determining virulence, and pathogenesis, particularly in endemic areas, can provide valuable insights for developing guidelines, effective treatments, and detection methods to control *S. suis* infections.

Current Output:

Publication: Lunha K et al., Relationship between penicillin-binding proteins alterations and beta-lactams non-susceptibility of diseased pig-isolated *Streptococcus suis*. Antibiotics (Basel) 2023;12(1):158.

Manuscript in preparation: Prevalence and serotype distribution of *Streptococcus suis* from healthy slaughtered pigs.

Future plan:

Whole-genome sequencing analysis for the rest of healthy pig-isolated *S. suis* is ongoing. Furthermore, comparative genomic study of distinct AMR *S. suis* isolates will be done to understand antibiotic resistance mechanisms, virulence factors, and also epidemiology of *S. suis* infection.

Integrating Biorefinery Process and Utilization of Soybean Meal for Plant-Based Protein Bioproduction Towards Innovative Future Foods

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 50%

Abstract:

This study investigated the use of *Lactobacillus plantarum* TISTR 926, *Lactobacillus casei* TISTR 390, and *Bacillus licheniformis* 46-2 for fermenting soybean meal. *B. licheniformis* 46-2, chosen by KMUTT, demonstrated a non-pathogenic 4,473,233 base pair genome, including genes for protein synthesis, amino acid metabolism, and Lasso peptide production. These strains collectively reduced phytic acid in soybean residue, enhancing nutrient absorption. Adding 20% rice flour and 2% oil improved texture during soybean residue restructuring. Adjusting moisture at a 50% initial content facilitated a smoother restructuring process. Overall, these bacterial strains show promise for enhancing nutrition and restructuring soybean meal.

Rationales/Problem statements:

This scholarly investigation is dedicated to elevating the nutritional profile of soybean meal through a meticulous fermentation process employing hybrid and consolidated bioprocessing techniques. The primary objectives encompass the refinement of amino acid and peptide production, the conduction of a comprehensive peptidomic analysis, and the scrutiny of novel aroma and flavor compounds. Furthermore, the study endeavors to craft a sophisticated method for texture restructuring utilizing state-of-the-art extrusion technology. The research framework incorporates meticulous mass balance and feasibility analyses, thereby contributing erudition and propounding prospective trajectories for the advancement of alternative protein and meat production paradigms within the discerning realms of the contemporary food industry, rooted in sustainable methodologies.

Objectives:

1. To develop a process for increasing the nutritional value of soybean meal through biological methods, utilizing enzymatic and fermentation processes to obtain bioactive peptides, vitamins, and bioactive compounds with properties different from those present in the original material.
2. To develop a process for shaping alternative food from enriched soybean meal through biological methods, and to study the physical properties and nutritional value.

Progress/Findings/Results:

Enzymes from plant sources, like papain and bromelain, resulted in a bitter taste when used to digest soybean residue. Therefore, *Lactobacillus plantarum* TISTR 926, *Lactobacillus casei* TISTR 390, and *Bacillus licheniformis* 46-2 were selected for fermentation due to their

safety. *B. licheniformis* 46-2, isolated at KMUTT, demonstrated safety in genomic analysis. It possesses protease enzymes with efficient activity in a neutral to alkaline pH range (7-11) and can produce aminopeptidase M. The strain also produces various secondary metabolites, including lasso peptides known for inhibiting bacterial growth. Additionally, *B. licheniformis* 46-2 carries crucial fermentation enzymes like peptidase, beta-amylase, and glucosidase, warranting further investigation.

In the fermentation of soybean meal with various strains over 2 days, a notable reduction in phytic acid content was observed. Analysis revealed that different strains contributed to a decrease in phytic acid levels. The control group exhibited 0.51% phytic acid in dried soybean meal. However, fermentation with *B. licheniformis* 46-2, *L. plantarum* TISTR 926, and *L. casei* TISTR 390 resulted in reduced phytic acid content to 0.33%, 0.38%, and 0.32% of the dried soybean meal weight, respectively. Phytic acid's inhibitory properties against nutrient-digesting enzymes, including trypsin, alpha-amylase, and lipase, make its reduction beneficial. This reduction enhances nutrient utilization by the consumer's body and diminishes the presence of antioxidant compounds in soybean residue.

To optimize the conditions for shaping soybean residue, the research team utilized a Co-rotating twin-screw extruder with a die temperature of 140 degrees Celsius and a screw rotation speed of 300 rpm. The soybean residue was divided into four experimental sets. Initially adjusting moisture content to 15% and 20% proved unsuccessful for shaping. Subsequently, the addition of 20% rice flour facilitated successful shaping, albeit with a relatively firm texture. Further adjustments, including the addition of 2% oil, improved shaping, resulting in a lighter and more porous texture. Future experiments are planned, intending to use fermented soybean meal and initiate shaping with an initial moisture content of 50% for enhanced process facilitation.

Conclusion:

This study revealed the limitations of plant-derived enzymes in soybean residue digestion, leading to undesirable taste. *Lactobacillus plantarum* TISTR 926, *Lactobacillus casei* TISTR 390, and *Bacillus licheniformis* 46-2 were chosen for fermentation, with *B. licheniformis* 46-2 proving safe through genomic analysis. It demonstrated versatile enzymatic capabilities, reduced phytic acid in soybean residue, and optimized reshaping conditions using a Co-rotating twin-screw extruder. These findings emphasize the strains' potential in enhancing soybean product nutrition and texture, paving the way for innovative soy-based products with improved sensory qualities.

Current Output:

- There is one graduate student at the master's level

Challenges/Problems and Possible solutions:

1. Chemicals ordered for antioxidant testing since July have not arrived, delaying experiments. Efforts to borrow from other labs were unsuccessful. Ongoing communication with suppliers to expedite delivery.
2. Research on shaping is on hold due to an extruder machine awaiting maintenance. Technicians scheduled to inspect on October 20th. Anticipate resuming experiments after this date, around October 20, 2026.

Future plan:

- Execution of a triple-strain fermentation trial.
- Determination of the amino acid profile derived from the fermentation process.
- Scrutiny of the restructuring procedure incorporating nuanced condition adjustments.
- Examination of the physicochemical attributes of the resultant products.

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนากำลังคนทักษะสูงและงานวิจัยขั้นแนวหน้า (Artificial Intelligence, Coding)

AI/Robotics for ALL Season 3

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Project duration: 1 year, from 1 August 2022 to 31 July 2023
Current progress: 85%

Abstract:
The coming of AI era makes the world rapidly change. This project aims to build human capacity by considering three steps, 1) Online Learning 2) Practical AI Camp and 3) Working with Company and Public Organization. There are 15041 registered to this program, 138 participants joined this AI camp and work with company/organization. 91 companies/organizations requested to accept participants from this program. We found that all participants who joined this project and participated in AI camp got the practical knowledge and skill, and possible to work for company/organization very well. We also develop weekly short programs by regional center, to develop online lectures and online hackathon. More than 1100 participants join the hackathon, and 488 participants can get better than baseline.

Rationales/Problem statements:
The coming of AI era makes the world rapidly change. It explores opportunities for innovation, quality improvement, and process improvement for better quality of life. However, there are too few people who can get the AI knowledge and skill for working in the company/organization. Participants from academic can get new skills for the AI task, participants who came from company/organizations achieved a new skill and reskill to apply for AI based task.

Objectives:
1) Build AI human resources.
2) Design a learning environment appropriated for AI.
3) Develop essential learning materials/platform for AI human capacity building.
4) Incubate Start up from the experienced company.
5) Pre experiment on human capacity building for non-degree program

Progress/Findings/Results:
Currently we have done the activity in 1) level 1: AIAT Mooc online learning implementation, Zoom online learning and hackathon online. We already gave an online certificate for all participants who achieve the base line result. 2) Level 2: AI engineer camp, there are 10 weeks in AI camp, week 1 and 2 for AI preparation, week 3 to 6 for onsite hackathon and week 7 to 10 for onsite hackathon. 3) Level3: Bringing AI engineer to work with company/organizations. We also developed a short program for participants who cannot join the AI camp. We found that there are many participants preparing for the next year by watching AIAT Mooc broadly. 4) AI engineer. There are 134 participants who joined the AI camp and got the certification. We found that a lot of companies prepared to accept AI engineers. It explored opportunity to work with others organization, such as providing data for hackathon, having a lecture from company/organization, accept participants to work and sponsor budget to this program. It strengthens the regional center to organize online level

work.

Conclusion:

Current Output:

134 participants participated in AI camp.

5 regional center who get the skill for organizing Zoom lecture and hackathon online.

4 Startup Company.

15,041 registered participants.

Challenges/Problems and Possible solutions:

Based on the human capacity project. We found that it is quite difficult to get an understanding for preparing AI topics with company/organizations in AI camp. It is necessary to verify and analyze whether it is appropriate for knowledge/skill acquisition or not. Moreover, the period of AI camp is duplicated to the school/university then there are around 50 participants who cannot join the AI camp. We plan to shift the AI camp period to get the opportunity for other participants. We plan to consult the company/organization in advance for the data preparation.

Future plan:

In the future, we would like to extend the opportunity for regional centers to develop the skill to organize similar tasks for AI engineer development. It is better to integrate the new AI technology to provide knowledge/skill to AI beginners. Finally, it should be an AI hackathon at an international level to explore the new opportunity with other countries.

Building Coders: Coding Consortium Northern Thailand

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 65%

Abstract: This project contains three subprojects as follows:

Sub-Project 1: STEM Coding. (Sub-Project Leader: Associated Prof. Dr. Sutthida Chamrat, Faculty of Education, Chiang Mai University)

Sub-Project 2: AI Innovators. (Sub-Project Leader: Prof. Dr. Narin Petrot, Faculty of Science, Naresuan University)

Sub-Project 3: Beyond coding. Sub-Project Leader: Prof. Dr. Rabian Wangkeeree, Faculty of Science, Naresuan University)

The overall current progress is 65%, and each project has already laid out a plan for the next steps, with completion scheduled for March 31, 2024.

Rationales/Problem statements:

This project is undertaken to develop human capacity in the northern region, tailored to the appropriate age group, with outcomes extending to employment opportunities and higher-level potential development. It focuses on enhancing and promoting coding skills among students, high school students, and the general public in the northern region's 17 provinces. The project is divided into three levels: lower secondary education, upper secondary education, and student/citizen levels. Participants at each level will have the opportunity to learn coding skills and relevant competencies suitable for their age group. They will have the chance to apply the knowledge acquired to real-life problems, fostering innovation and creativity. The project will establish a centralized system to monitor the progress of each participant and consolidate teaching materials, instructional media, and various knowledge assets generated throughout the project for sustainable development.

Objectives:

3.1.1 This project is undertaken to develop human capacity in the northern region, tailored to the appropriate age group, with outcomes extending to employment opportunities and higher-level potential development.

3.1.2 This project is designed to develop and promote coding skills among students, high school students, and the general public in the northern region's 17 provinces. It is divided into three levels: lower secondary education, upper secondary education, and student/citizen levels. Participants at each level will have the opportunity to learn coding skills and relevant competencies suitable for their age group. They will have the chance to apply the knowledge acquired to real-life problems, fostering innovation and creativity.

Progress/Findings/Results:

Sub-Project 1: This project, aimed at developing a learning platform to foster competency in STEM and coding, has been initiated with an open learning approach for the general public and innovation camps targeting startups and young entrepreneurs for junior high school students. The project commenced after receiving approval from the Research Ethics Committee, Chiang Mai University, certified under research project code CMUREC 66/144, with a Certificate of Exemption (COA No.031/66) issued.

To introduce the project, three sub-projects were collectively promoted through a Webinar (Soft Launch) activity on June 23, 2023. Subsequently, on July 21, 2023, Sub-project 1 conducted a Webinar (Soft Launch) to publicize activities, including collecting data on

objective 1 and opening registrations for teachers via the project website https://www.lifelong.cmu.ac.th/stemcoding.

For the MOOCs lesson component, the research team developed six lessons comprising a total of 51 video lessons and one STEM Coding Empowerment curriculum booklet. These lessons are accessible on the website https://powerclass.org, with 62 schools, 69 teams, and 337 participants enrolled.
This progress report is currently in phase 5, with the Innovation Camp scheduled for October 3-5, 2023, and October 17-19, 2023.

Sub-Project 2: This project is a collaboration among 9 universities in the northern region. The common goal is to promote and develop the youth's abilities in the northern region, enhancing their potential in mathematics, computational thinking, and advanced coding. The ultimate aim is to foster expertise in artificial intelligence. As of the reporting period, four planned activities have been implemented:
Activity 1: Conducting a meeting to design the training curriculum and prepare tools for training.
Activity 2: Publicizing the project and recruiting students.
Activity 3: Organizing a competition to select students for the AI Innovator Bootcamp, held on the 8th Network Center.
Activity 4: Hosting the AI Innovator Bootcamp at the main center of Naresuan University.

Sub-Project 3: The "Beyond Coding" project, aimed at developing traditional and new skills in mathematics and programming for advanced education students, researchers, innovators, and the general public to prepare for the job market, has been officially introduced. In the online segment, the research team developed ten courses comprising a total of 100 video lessons, accessible on the website https://powerclass.org.
As part of the project's activities, on October 8, 2023, the "Beyond Coding: Solve Fest 2023" was organized as an online event. The event aimed to provide participants with the opportunity to get to know the project's staff and engage in games that required mathematical, computational, and problem-solving skills. Participants earned cumulative scores based on their performance and submission times.
Conclusion: The overall current progress is 65%, and each project has already laid out a plan for the next steps, with completion scheduled for March 31, 2024.
Current Output:

1. Website: https://www.lifelong.cmu.ac.th /stemcoding
2. Website: https://research.sci.nu.ac.th/ai/
3. YouTube Channel : https://www.youtube.com/@TheAIInnovatorsProject
4. Online Learning on the Platform : https://powerclass.org

Challenges/Problems and Possible solutions:
To create continuity for the development of youth who participate in the project's activities and are part of the systematic database, in order to leverage the database to foster growth and development of these youth towards the goals, by recognizing and utilizing the benefits from this youth database in every sector.
Future plan: Each project has already laid out a plan for the next steps, with completion scheduled for March 31**,** 2024.

Model of Learning Ecosystem Platform Integrate with Coding & AI for Youth

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Project duration: 1 year, from 28 April 2023 to 27 April 2024
Current progress: 80%

Abstract: This research aims to enhance Coding and AI competencies among youth through various initiatives. Firstly, it focuses on creating a learning environment leveraging the Code Combat platform and educational AI innovation, catering to youth across different skill levels. Secondly, it seeks to establish a lifelong learning curriculum and innovative online education in AI-related areas, recognized by Khon Kaen University. Collaborating with entrepreneurs, the objective is to empower youth by imparting specialized knowledge in Blockchain, Fintech, AR-E-Sport, BCG Industrial-IoTs Factory, Data Science and Personal AI. This collaboration aims to prepare them for advanced professional domains through group projects and Hackathon Pitching. The research also includes fostering collaborative networks, developing competency maps, and conducting skill enhancement programs for teachers and a wide demographic of individuals, promoting ongoing assessments for Coding and AI competency. Results showcase the development of learning ecosystems, specialized online courses, assessment tools, collaborative networks, and ongoing skill development programs benefiting educators and diverse learners.

Rationales/Problem statements: Developing human resources to enhance competitiveness is crucial, especially in the digital industry that drives economic growth through research and innovation. Education is pivotal for adapting and evolving skills to meet current demands, considering a potential 50% job reduction due to the integration of automated systems (World Economic Forum Annual Meeting, 2020). Learning new skills, particularly in computer language (Coding), is vital to prepare Thais for the 21st century, aligning with technological changes (Daniel Ehlers, 2020). The global trend emphasizes promoting Coding even at the elementary level to bolster mathematical skills and critical thinking (Megan & Elena, 2019). This study focuses on an integrated learning ecosystem in Coding & AI, using platforms like Code Combat and AI educational innovations. It aims to cultivate Coding & AI skills across different levels, linking with businesses and industries. Additionally, it aims to create learning mechanisms for youth, students, and educators, fostering collaborations for workforce readiness (Daniel Ehlers, 2020).

Objectives: 1. To develop learning ecosystem to enhance coding & AI skill with Code Combat platform and educational AI innovation for youth

2. To create and disseminate lifelong learning curriculum and online education innovation in AI-related Coding and AI intelligence through lessons and learning platforms issuing micro-credential-supported credits recognized by Khon Kaen University.

3. To empower youth: collaborate with entrepreneur & partnership to advance Coding and AI skills. This includes specialized knowledge in theme such as Blockchain & Fintech, AR-E-Sport, BCG Industrial-IoTs Factory, Data Science, and Personal AI. The goal is to prepare them for higher professional fields through group projects and Hackathon Pitching.

4. To Foster Coding & AI collaborative research: establish a collaborative network among

public, private, and independent researchers specializing in educational research and innovation in fields related to Coding, Computational Science, and AI. This will involve practical applications to solve computer science-related challenges and advance Coding and AI knowledge.

Progress/Findings/Results:1. Developed a Learning Ecosystem to Enhance Coding & AI Skill with Code Combat Platform and Educational AI Innovation for Youth across four levels: Beginners, Pre-Intermediate, Intermediate, and Advanced.

2. Designed Online Courses to Enhance Advance Coding & Skill for Youth tailored for collaboration with entrepreneurs via the PMU-B Thailand Coding Academy platform. These courses cover Blockchain & Fintech, AR-E-sport, BCG Industrial-IoTs Factory, Data Science, and Personal AI.

3. Created assessment tools for coding and AI skills evaluation across two proficiency levels: Basic and Advance Coding & AI Skill.

4. Established a Coding & AI Collaborative research consist of 24 academic institutions in the public sector and 14 private sector/industry.

5. 480 participants utilizing the Learning Ecosystem to Enhance Basic Coding & AI Skill with the Code Combat Platform and Educational AI Innovation for Youth. the project result shows that participants had varying levels of proficiency in Basic Coding & AI Skill, with 188 (39.17%) participants categorized as Beginners (CS1), 70 (14.58%) as pre-Intermediate (CS2), 121 (25.21%) as Intermediate (CS3 – CS4), and 101 (21.04%) as Advanced level (CS5 – CS6).

Conclusion: The study produced a comprehensive learning framework, fostering Coding & AI competencies across four progressive tiers. Tailored Online Courses, shaped in collaboration with entrepreneurs via PMU-B Thailand Coding Academy, delved into specialized fields like Blockchain, Fintech, AR-E-sport, BCG Industrial-IoTs Factory, Data Science, and Personal AI. Innovative assessment tools effectively evaluated two tiers of Coding & AI proficiency. Furthermore, a robust research coalition was established, uniting 24 public and 14 private academic entities in Coding & AI exploration. The engagement of 480 participants revealed diverse skill levels: 188 (39.17%) Beginners (CS1), 70 (14.58%) pre-Intermediate (CS2), 121 (25.21%) Intermediate (CS3 – CS4), and 101 (21.04%) Advanced (CS5 – CS6) proficiency levels.

Current Output: 1. Learning Ecosystem to Enhance Basic Coding & AI Skill with Code Combat Platform and Educational AI Innovation for Youth : Beginner, pre-Intermediate, Intermediate and Advance

2. Online Courses to Enhance Advance Coding & Skill for Youth tailored for collaboration with entrepreneurs via the PMU-B Thailand Coding Academy platform: 1) Blockchain & Fintech 2) AR-E-Sports 3) BCG Industrial-IoTs Factory 4) Data Science 5) Personal AI

3. Assessment tools for coding and AI skills evaluation across four proficiency levels: Beginner, Pre-Intermediate, Intermediate, and Advanced.

4. Coding & AI Collaborative research consist of 24 academic institutions in the public sector and 14 private sector/industry.

Challenges/Problems and Possible solutions: The innovations achieved in each profession can lead to patent applications in collaboration with entrepreneurs, potentially advancing toward commercialization.

Future plan: 1. Hackathon and pitching competition activities.

2. Seeking approval for short-term courses (**6** courses) from the Faculty of Education, Khon Kaen University, to accumulate credits in further education (Pre-university/Graduated).

Developing Special Talents in Programming Through an Integration of Mathematical Modeling and Artificial Intelligence to Deepen Understanding the Link Between Brain Function and Behavior

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 70 %

Abstract:
The "AI Builders" project has trained 46 students and hosted an "AI Builders Showcase" to present their work. AI Builders has submitted its report and its list of high-skilled trainees .
The "Brain Building Blocks" project has developed a comprehensive online computational neuroscience course and contents for the public. Its content has received 16,000 views in just six months. It is now focusing on developing a competency map for microcredentials accreditation, together with Brain Hackathon.
"Brain Code Camp," has enrolled 50 students for the program. These students are now in their 7th out of 12th week of the computational neuroscience training program, receiving hands-on experience in coding and handling of real data. Concurrently, it is adapting its contents for train-the-trainer project in collaboration with Brain Hackathon.
The "Brain Hackathon" project has successfully attracted key partners from the government and private sector to host the Brain Hackathon competition to solve real-world problems.

Rationales/Problem statements:
In the last decade, there has been a significant leap in science and technology, greatly influencing global society and leading to various innovations. This has included the integration of technology education in Thailand's curriculum to prepare youth for future challenges. The focus is not just on programming skills but on developing logical and scientific thinking for problem-solving and application in real-life scenarios. Computational neuroscience and related fields like AI and BCI are increasingly important, combining multiple disciplines to understand and replicate brain functions. Our program offers a comprehensive approach that aims to equip individuals with the skills and knowledge for practical application in their studies and future careers, contributing to Thailand's long-term development.

Objectives:
1. To promote the development of Coding skills and STEAM Thinking for high school students and university students from interdisciplinary fields.
2. To develop and disseminate lifelong learning computational neuroscience curricula in the form of micro-credentials, supported by leading universities.
3. To develop a network for research and advanced human resource development between public and private sectors.
4. To develop a Competency Map for the development of coding manpower in Thailand.

5. To study and develop a system for linking data of individuals with special talents to other talent development projects, leading to the National Talent Pool in Coding.

Progress/Findings/Results:

1. Brain Building Blocks (76.25% completed)
    - The program has created an online computational neuroscience course, as well as, podcast episodes to raise awareness for computational neuroscience for the public. The course and podcast episodes are currently available. A certificate can be awarded to those who has completed the course and passed the competency exam. The program has made preparations for the upcoming train-the-trainer program. Collection of course evaluations are on-going and will be summarised at the end of the year.
    - So far, its online contents have received over 17,000 views and over 600 subscribers to its channel. Twenty-nine participants have completed the course and passed the competency exam.
2. Brain Code Camp (63.5% completed)
    - The program has crafted an online hands-on coding and computational neuroscience course and workshop. It has completed its selection process of 50 high-potential students. The course is still ongoing in its 7th out of 12th week.
    - All 50 students that had passed the application examination and selection process were well-equipped with basic computational neuroscience knowledge (available from Brain Building Blocks). After several weeks of training, students are more competent in using AI and modeling to solve problems proposed by instructors in each training session and are engaged in conducting their personal projects using their own/prepared datasets.
3. Brain Hackathon (13.5% completed)
    - The program has prepared materials and promoted the train-the-trainer programs through various channels. It has also contacted key players from both private and government sectors to co-host the Brain Hackathon competition which will take place from 18 November 2023 to 20 January 2023.
    - The program has attained valuable key partners that will together foster applicants from AI Builders and Brain Code Camp. The competition will require applicants to apply and integrate their skills in solving real-world problems.
4. AI Builders (100% completed)
    - The AI Builders project has trained 46 students during a 10-week intensive artificial intelligence and machine learning course. It had also hosted a AI Builders Showcase on the 2nd July 2023 to present their students' projects.
    - The AI Builders Showcase was well-received by its stakeholders from both government and private sectors. Many of its students were able to further their career by obtaining internships at leading institutions, presenting their works at international conferences, and participating in other various AI and hackathon competitions.

Conclusion:

All programs have achieved outcomes and progressed according to the initially proposed timeline. Most programs have attained wide popularity amongst high-school students, university students, and professionals. The programs received more applicants than anticipated, and hence, were able to select high-potential students into the programs.

Current Output:

- A publicly-available online-learning course on Cognitive Computational Neuroscience at www.youtube.com/@braincode101 with 700+ subscribers and 20,000+ views
- A web-based computational neuroscience course at https://course-braincodecamp.web.app
- Virtual workshop "AI builders": Students' showcases are available at https://ai-builders.github.io
- Virtual workshop "Brain Code Camp": Students' showcases are available at https://course-braincodecamp.web.app/GeneralInfo/projects.html?fbclid=IwAR1JQInH4VtTWYLP7yKl5nx-fyu2FNq_FZpp5DBf4IhW_1GwqRhGOkt1tQQ
- Brain Hackathon workshop kickoff at DTGO on 18th-19th November, 2023
- Student exchange: 2 students at UCSD, 1 student at Ernst-Strungmann Neuroscience Institute
- Two international conferences: UCL x MDCU neuroscience seminar (1-2 September 2023) and MLRS2023 (2nd-9th August 2023)

Challenges/Problems:

Our program saw a high turnout, resulting in a dynamic blend of students with diverse backgrounds, skills, and interests. Adapting our teaching to accommodate varying expertise levels stands as our foremost challenge. Some students managed the class alongside their ongoing school assignments and exams, striking a balance between academics and lessons. Furthermore, given that this marks our debut year, the tight time frame between PR activities and the coding camp and hackathon contest itself poses a difficulty. This scenario might present a hurdle for students eager to join but lacking in fundamental coding skills.

Possible solutions, Future plan:

Over the past year, we've made all our teaching materials available online for students, ensuring free access. Our upcoming plan involves offering a spectrum of lessons, spanning from fundamental basics to intermediate skills suitable for work. Students have the flexibility to start at their convenience, preparing themselves for program activities. We've crafted a learning path aimed at guiding students seamlessly through their lessons, enabling an on-demand process that facilitates catching up after school-related breaks. With better-prepared students, we aim to incorporate additional neuroscience elements into our lessons, potentially expanding our teaching scope.

Development of Digital Citizens to Support the Smart Farming Industry with STEM, Coding, IoT and AI

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 70%

Abstract:
Promote more knowledge and ability in science, mathematics and technology. Computational skills, problem solving, application of digital technology in agriculture through the digital citizenship development project to support the smart agriculture industry with STEM, Coding, IoT and AI using the open innovation HandySense developed by Thai people. that can help accurately manage agricultural conversion systems Use with smart farms that have environmental sensor technology and automated agricultural control systems designed to be easy to use. and environmental sustainability So that project participants can access and use modern technology. To increase income and reduce production costs for farmers Including the efficient use of resources and being able to increase farmers' income by at least 20%.

Rationales/Problem statements:
Thailand is considered the kitchen of the world. Income from growing crops Accounting for as high as 68 percent of all agriculture. So that farmers can produce agricultural products for export with full efficiency. and can adapt to the digital age Through the use of knowledge in computation, statistics and technology to help adapt to the changes that occur. Through a platform to learn coding for agriculture smart farm system Precision agriculture farms that are automated and have high accuracy such as temperature measurement. Measuring air humidity and soil moisture, etc. by ordering an automatic watering system So that farmers can control and monitor their farmland from remote areas. through the application and create an understanding of appropriate space management and use resources efficiently Increase efficiency and effectiveness for farmers.

Objectives:
1) To develop a prototype curriculum to develop the potential of teachers and students in rural areas, STEM and digital technologies such as Coding, Embedded System, AI, Internet of Things, to create a new generation of farmers. Through the Smart Agriculture Science Project
2) To develop a short training course on basic artificial intelligence prototypes in smart agriculture. Through the use of the AIThaiGen learning platform to receive advice on developing smart agriculture.
3) Create designers and transfer technology for intelligent agricultural plot management systems with HandySense to use in agricultural plots and create careers as designers of intelligent agricultural plots. To plan and be able to use the HandySense device application to show actual agricultural plots/planting areas.

Progress/Findings/Results:
ĩSub-Research Project **1:** STEM and Coding Skills Development Project for Rural Youth
: Learning activities for coding and embedded systems, Internet of Things (IoT) learning activities and project proposal writing, Select teachers and students to participate in activities. “Smart Agriculture/Precision Agriculture”, Learning activities Smart Agriculture/Precision Agriculture Project (study visit).
Sub-research project **2:** Developing digital citizenship to support smart agriculture through

artificial intelligence learning platform: AITHAIGEN
: Develop a prototype learning kit for smart agriculture, Design an artificial intelligence training course for smart agriculture, Prepare teaching media, teaching media, Create a prototype learning kit for smart agriculture, Basic artificial intelligence technology training, Python Programming Training.
Sub-research project **3:** Designer/developer of agricultural plot management system using Internet of Things (IoT) technology, open innovation, HandySense.
: Survey and select area and invite educational institutions to participate in training, Training Basic knowledge on agricultural plot management systems using Internet of Things (IoT) technology by HandySense open innovation, and study visits, Activity to follow up on technology application, Design of agricultural plot management system With Internet of Things (IoT) technology by HandySenes.

Conclusion:

Develop project participants with STEM, AI, IoT and coding skills to create knowledge and understanding for innovators in smart agriculture. Through HandySense precision agriculture technology To create income reduce costs and create a career as a SMART FARM technician and Designer of the intelligent agricultural plot management system.

Current Output:

Sub-Research Project **1:** Project to develop STEM and Coding Skills for rural youth.
: Project activity participants: **499** high school students from the target of **240**, high school teachers **160** people, network schools, **64** schools/institutions from the target of **60** schools/institutions and **46** agricultural science projects from the target of **40** projects.
Sub-research project **2:** Developing digital citizens to support smart agriculture through the artificial intelligence learning platform: AITHAIGEN
: Project activity participants: 32 high school students, 5 high school teachers, 30 vocational students, 2 vocational teachers, 49 students, 4 university professors, 10 secondary school projects, 8 student projects
Vocational level projects, 4 projects
Sub-research project **3:** Designer/developer of agricultural plot management system using Internet of Things (IoT) technology, open innovation HandySense.
: Project activity participants: **6** high school students, **9** vocational students, **9** students, **6** control officer, **8** vocational teachers, **7** university professors, **2** community enterprises, and **1** private company, totaling **48** people and **8** HandySesne technology application areas.

Challenges/Problems and Possible solutions:

1) Consulting To develop science project proposals To be consistent with the real context and be able to conduct experiments Test for efficiency
2) Following up on the application of HandySense technology to provide recommendations and solutions.

Future plan:

1) Promote science projects to be used in real life or in real areas. To gain understanding and see opportunities for development into a career.
2) People who have passed the training Designer/developer of agricultural plot management system using Internet of Things (IoT) technology, open innovation, HandySense, entering into entrepreneurship. Smart Farm Technician Designer of automatic agricultural plots Registered as an entrepreneur (Digital Provider) of the Digital Economy Promotion Agency.
3) Promote the development of the HandySense technology curriculum in collaboration with the Central Agricultural Vocational Institute. (10 Agricultural and Technology Colleges)

Talent Robotics, AI, and Coding Academy and Consortium Development

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Project duration: 1 year, from 1 April 2023 to 30 March 2024
Current progress: 70%

Abstract:
Talent Robotics, AI, and Coding Academy and Consortium Development Project is a collaboration between KMUTT, NECTEC, IPST and KMUTNB. This project aims to develop skills in Robotics, AI and Coding (RAC) for talented high school and vocational school students, mainly from educational institutions in Bangkok Metropolitan Region. The activities are as follows: 1) *Development* is the establishment of network cooperation between universities in collecting the information about a coding competency to create a database of talented people in Coding and RAC, 2) *Recruitment*, this activity starts with creating a network (Consortium) between schools, universities, private and government sectors with different areas of knowledge and expertise, 3) *Enhancement* is the activity for developing learners entering the system to increase their competencies in RAC, with emphasis on hands-on learning in both online and onsite formats, and 4) *Assessment* is implemented for the determination of competencies of students after participating in Enhancement activity.

Rationales/Problem statements:

Coding is fast becoming one of the most important subjects taught since elementary schools. This practice ensures that students have a strong foundation in coding and learning coding skills early strengthens the base for advanced concepts of coding, robotics and AI in future. Learning to code is not just for students who wish to become computer programmers or engineers. Through coding, students learn to think algorithmically, break down complex problems, and apply logical thinking, computational thinking, systematic thinking and analytic thinking. Furthermore, students are learning employability skills such as teamwork and collaboration, problem solving, the ability to fail and persevere, and more. It is necessary to find a way to develop skills that can create interest and develop youth in a broad area effectively.

This project therefore aims at enhancing the cooperation between schools, universities, private and government sectors to promote the competency in RAC at high school and vocational levels. Learning activities are organized to encourage talented students to increase their competencies in RAC. Project success factors will also be investigated. The project will further link to Talent Utilization Platform (Talent Thailand).

Objectives:

1. To enhance skills in RAC of talented high school and vocational school students, mainly from educational institutions in Bangkok Metropolitan Region.
2. To study and develop a coding competency map for developing the coding workforce in Thailand.
3. To study and develop a system for linking the data of talented people to National Talent Pool in the field of coding.

Progress/Findings/Results:

The competency map is in progress for Thailand's coding workforce that can measure the level of individual proficiency in coding for beginners and for experts in at least 1 field. The database is now in the process of creating in order to link the information of talented people to National Talent Pool. Over 1,000 students have been developed to have more skills from learning and participating in learning activities through online and onsite lessons in RAC. Work-integrated learning (WiL) enables students to experience real world problems and to develop generic professional skills. High school and vocational school administrators understand and become aware of the importance of RAC.

Conclusion:

This project has developed and organized activities in various areas to enhance student competencies in RAC. The consortium for school, university, private and government sector networking is established to support the development of talented students. In this project. learning online and onsite can help the learners developing their skills in RAC. There is also a study and development of the competency map for the development of Thailand's coding workforce. Public hearings have been held to consider the details of the coding competency framework.

Current Output:

1. Curriculum/course content for RAC, 6 subjects.
2. Potential development of 1,274 students and teachers in RAC through online lessons.
3. Potential development of 100 students through learning and participating in learning activities with research institutes and industrial companies.
4. Potential development of 95 teachers in RAC through onsite training.
5. Signing of MOU between KMUTT, NECTEC, IPST and KMUTNB and 128 high schools and vocational schools.

Future Plan:

1. Design an assessment to evaluate coding competencies of students.
2. Follow up on the results of students who participated in activities during and after the project ends.
3. Evaluate all impacts that occur on teachers, schools, communities, society, and countries.

Development and Transfer of Technology, Artificial Intelligence Techniques in the Diagnosis of Patients with Brain Injury

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 64%

Abstract:
The most common cause of long-term disability and death in young adults is traumatic brain injury (TBI). Computer Tomography (CT) is the gold standard technique for brain injury evaluation after acute TBI. This research aims to develop AI-assisted software for diagnosing TBI from CT scans. The software consists of tasks in the detection, classification and quantification of intracranial hemorrhage, shifting of midline structures, and skull fractures as well as suggestion of the need for surgery. Machine learning models and image processing techniques are adopted for those tasks. For the current state, the developed software achieved accuracy, sensitivity, and specificity of 90%, 86% and 94%, respectively, in a preliminary test. During the AI development process, the knowledge in both AI and medical aspects from the research was also transferred to external radiologists via workshops organized by the researchers.

Rationales/Problem statements:
Traumatic brain injury (TBI) is the most common cause of long-term disability and death in adolescents. Availability and low acquisition time make computer tomography (CT) a commonly used first-line diagnostic modality. In the case of TBI, time-sensitive abnormalities that are highly accurate in the detection on CT scans include intracranial hemorrhage, shifting of midline structures, and skull fractures. Detection and classification of these lesions are critical in the medical decision-making process of surgery. However, the number of radiologists available to interpret the CT scans has often been limited. AI-assisted software can be used efficiently to assist physicians in their decision-making by providing high computational power and accessibility. Its use can also decrease the time for assessment in emergency situations.

Objectives:
1. To develop AI software for assisting in diagnosing patients with brain injury.
2. To develop researchers who have high potential in developing AI-assisted tools for radiological diagnosis.
3. To train and encourage physicians to adopt AI-assisted tools for diagnosing patients with brain injuries.

Progress/Findings/Results:
In the current state, we have developed AI models for segmenting hemorrhage subtypes and detecting skull fractures on a CT scan. In addition, quantification methods were applied to the segmentation results to measure hemorrhage volume and thickness. Also, a method for

assessing midline shifts has been proposed. The outcomes derived from the detection and quantification of these abnormalities were used to construct a machine-learning model for identifying patients who need surgical treatment. The results from a preliminary performance evaluation highlight the model achieving accuracy, sensitivity, and specificity of 90%, 86%, and 94%, respectively. Moreover, we deployed the developed model as a web-based software, named AIRAD TBI. The software is running in the phase of testing. Meanwhile, we have organized two workshops on basic AI in radiology for training physicians and others to understand how AI is developed and works. The workshops received good feedback from attendances. Now, we are preparing a workshop for demonstrating and training physicians from external hospitals in the use of the AIRAD TBI software. All seats in the workshop have been fully reserved.

Conclusion:

At this point, our software operates admirably. The next stage is to try to implement it in the pilot hospital. It will begin when the radiologist and trainee radiologist have gone through our workshop session. Further research evaluating the potential of AIRAD-TBI software-assisted tools for radiologists is planned.

Current Output:

1. Inkeaw P., Angkurawaranon S., Khumrin P., Inmutto N., Traisathit P., Chaijaruwanich J., Angkurawaranon C., Chitapanarux I. Automatic hemorrhage segmentation on head CT scan for traumatic brain injury using 3D deep learning model. Computers in Biology and Medicine. 2022; 146: 105530.

2. Angkurawaranon S., Sanorsieng N., Unsrisong K., Inkeaw P., Sripan P., Khumrin P., Angkurawaranon C., Vaniyapong T., Chitapanarux I. A comparison of performance between a deep learning model with residents for localization and classification of intracranial hemorrhage. Scientific Reports. 2023; 13: 9975.

3. Chaidee S., Inkeaw P., Makee T., Khamyod K., Angkurawaranon S., Trisathit P., Vaniyapong T., Chitapanarux I. Comparative Analysis between Different Volumetric Methods on Measuring Intracranial Hemorrhage Incorporating Roundness Index. PLoS ONE. 2023; 18(10): e0292092.

Future plan:

In the future, we plan to test our software on a large number of cases and also try to use external validation from the cases of other hospitals. Not only for the software but also for the prediction model that we made to help with prediction management that was needed by the patient from CT scans of the brain in patients with traumatic brain injury.

Project title: Research and Development of a Knowledge Base to Apply Artificial Intelligence (AI) Models and Frameworks for Medical and Healthcare System in Thailand Society

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 67%

Abstract: Artificial intelligence (AI) is being developed and applied in every sector to meet new challenges. It causes changes in human well-being, economic prosperity, quality of life and safety. In this research, AI research and development in medicine and health care is presented. It presents an application that uses AI to diagnose Stroke, Remote rehabilitation system and diagnosis of eye disease. Currently, these problems have a significant impact on Thai society. In addition to the proposed AI techniques, AI frameworks and infrastructure are used together to continue creating knowledge and supporting the use of AI in medicine and health care in Thailand.

Rationales/Problem statements: Stroke is a leading cause of disability and death in Thailand. Meanwhile, comprehensive rehabilitation for patients with significant disabilities is available at only a few large hospitals. In addition, macular degeneration is the most common disease group, especially in people over 50 years of age. Therefore, early detection of the disease is essential. It will result in easier treatment. Therefore, this research focuses on the application of AI techniques and frameworks for the medical and healthcare system in Thai society by presenting a deep learning model for stroke detection, a telerehabilitation system based on an AI video analysis model and an AI model for eye disease diagnosis.

Objectives:

1. Create new basic knowledge in the use of AI and frameworks for medical and health care systems in Thai society.
2. Propose a deep learning model for stroke detection.
3. Propose a remote rehabilitation system based on the AI video analysis model.
4. Propose an AI model for diagnosing eye disease.
5. Develop AI tools and increase high-level research personnel and build a knowledge based on the use of artificial intelligence in the country's medical and health care sector.
6. Promote the use of AI as a basis for driving the country's economy and society.

Progress/Findings/Results:
Currently, we are still conducting research according to the plans and activities that have been set out. Over the past period, we have carried out research studies and collected various relevant data sets for training AI models. This project is to have a prototype AI system with prediction of accuracy equal to or higher than the State of the Art of currently available models. The results of the research so far are as follows:

1. Deep learning model for stroke detection: CT scan brain image data is stored in Google Drive, then the proposed AI is designed for vascular disease detection and the performance of the model is tested, including VGG19, Efficient Net B7 and Inception V3, as well as developing and training an AI model for detecting lung cancer and testing the performance of the SHOA-DNN model, which can show the results of tumor classification into 3 categories: normal, lung tumor, malignant and benign lung tumors.

2. Telerehabilitation system based on video AI analysis model: A dataset was collected, and AI was trained through the Google Colab Pro platform to design and build an ML model for physical therapy focusing on the lower limbs of inpatients. The three exercises include hip flexion and external hip rotation. And knee extensions and tested the accuracy of the ML model developed for remote physical therapy.

3. AI Model for Eye Disease Diagnosis: The Chula-AMD eye image dataset was collected to train and build an AI model to classify macular degeneration syndromes on the Google platform, and then research, design and develop the training platform. And tested with DLNN and ViT models to classify eye disease syndromes into 3 categories: Normal, Dry AMD, and Wet AMD. From training and testing, it was found that the model results ViT16 has the best performance in terms of accuracy and sensitivity.

Conclusion: Performance results from months 1-24, the research team has designed and laid the foundation for conducting research according to the plan in the project proposal. By researching and collecting various relevant data sets. To be used to train the AI model that will be developed according to the stated goals of the research in this project, the three prototype systems are (1) a prototype system and AI model for detecting stroke/cancer; lungs, (2) prototype system and AI model analyzing videos for remote physical therapy, and (3) prototype system and AI model classifying macular degeneration syndromes from eye images. Currently, the research team has designed, developed, and tested a web app using AI according to the proposed method. In addition, 2 research papers have been submitted for publication in foreign academic journals, Q1 or Q2 level, and 5 more papers are in the process of being submitted for publication.

Current Output:
- Published to international academic journals (Q1 or Q2 level) : 2 units
- In the process of publication: 5 units

Challenges/Problems and Possible solutions: - Not have -

Future plan: Develop AI accuracy to be more accurate along with web application frontend development. The Streamlit library will be chosen to develop an interface for doctors. For the testing must be carried out in accordance with the conditions and recommendations of the user's doctor to provide work in putting it into practice and expanding knowledge in the future. Then the least 3 more articles will be written about testing with user's doctor.

Automated Analysis of Retinal Images for Detection of Diabetic Retinopathy Using Artificial Intelligence (AI)

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 65%

Abstract:

Diabetic retinopathy (DR) is a type of eye disease caused by high blood sugar levels which can lead to vision loss. DR is the leading cause of blindness in the global working-age population in developed nations. Ophthalmologists can manually identify DR by looking at retinal fundus images and analyzing the DR lesions. However, the process of manually examining fundus images for signs of lesions and related symptoms is difficult and requires a significant amount of time and effort for the ophthalmologist. Therefore, automatic screening the disease by computer-aided has become a promising tool. However, most currently DR screening algorithms do not achieve satisfy performance; because the foreground information like the blood vessel network emerging in heterogeneous background information as such retinal texture, optic disk, fovea, and disease lesions occurring in the retina.

Problem statements:

DR screening algorithms do not achieve satisfy performance; causing from many factors, firstly, almost datasets providing only DR lesions and some datasets providing wrong annotation as such vitreous hemorrhage (VH, which occurring in the last state of DR) labelled with hemorrhage. Secondly, labelling error, etc.

Objectives:

To design DR screening algorithm, which provides both DR levels and DR-lesion segmentation.

To produce good quality dataset for DR lesions.

Progress/Findings/Results:

We have 88 images of PSU dataset, and some images of IDRiD and DDR datasets were corrected; thus, the pixel level annotation was labelled 245 images.

Conclusion:

In the fourth research report, we spent a significant amount of time correcting labeling errors in both the IDRiD and DDR datasets and creating the PSU dataset. Therefore, our dataset includes pixel-level annotations for 7 diabetic retinopathy lesions across a total of 245 images. The dataset was used to train the DeeplabV3+ model. We believe in our improving the datasets, which have labelling errors less than the original datasets. From testing with the DDR dataset by selecting the images, which are identified as no DR lesions (DR-level-0) consisting of 60 images. The trained model detects with MA, EX, and HE lesions with 9 images, which provide the labelling error proportion equal to 8%.

Current Output:

Vonghirandecha, P., Kansomkeat, S., Bhurayanontachai, P., Sae-Ueng, P., & Intajag, S. (2023). Decorrelation stretch for enhancing colour fundus photographs affected by cataracts. *Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization*, 1-12.

Challenges/Problems and Possible solutions:

The verification of DR lesions on the retinal images by ophthalmologists for the creation of the PSU dataset requires a high level of precision and involves a significant amount of time.

Future plan:

In the future, enhancements will be made to the model, enabling it to not only detect DR lesions in retinal images but also assess the severity of DR.

Machine Learning Based Model with Weighted Objective Distance for Classification of Elderly People with Dementia Risk: A Case Study of Elderly People Group in Upper Northern of Thailand

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Project duration: 3 year, from 1 November 2021 to 31 October 2024
Current progress: 60%

Abstract:
Dementia is one of the major causes of disability and describes a loss of thinking ability, memory, attention, logical reasoning, and other mental abilities. It is crucial for elderly people with dementia risk to have early access to support information and medication if necessary. This study promotes the early detection of dementia by proposing a machine learning-based model for the classification of elderly people with dementia risk. The data from the last 5 years of regular health checks, which is collected from the hospitals in upper northern Thailand, is used for model construction and evaluation. The features used for constructing the model consist of personal data and clinical data about each person. These features are transformed into an individual health measurement called the Optimized Weighted Objective Distance (OWOD). The classification performance is compared with many machine learning-based methods to obtain the best classification model.

Rationales/Problem statements:
Dementia is a condition in which the patient has a decline in intelligence, behavior, and personality in daily life. Cerebrovascular diseases cause most dementia, along with obesity, smoking, drinking, depression, etc. The early detection of elderly people with dementia risk is crucial, which is the objective of this research project. Traditional early detection requires a full-factor diagnosis from an advanced laboratory, which not all seniors can access. For this study, the early detection of elderly people with dementia risk is mainly focused on by constructing the classification models using the data from regular health checks. Previously, several constructed models have been built to distinguish a person with dementia from a healthy person. Many effective models were built from the different datasets and different machine learning methods. This study uses data from upper-northern Thailand hospitals to construct an effective model utilizing modified weighted objective distance, an individual health measurement.

Objectives:
This study aims to propose a machine learning-based model for the classification of elderly people with dementia risk and modify the individual health measurement, which is a weighted objective distance (WOD), for constructing an effective classification model for elderly people with dementia risk.

Progress/Findings/Results:
The current progression consists of the construction of a classification model with different machine learning-based methods using feature engineering and the modification of the WOD.
For the construction of classification models, the main focus of this study is on both binary and multi-class classification models. The dataset is from hospitals in Chiang Rai province. Different feature engineering methods are applied to the raw data. The models are constructed and tested with different sizes of datasets, with a minimum of 10,000 records. The results show that the model from ensemble learning groups can provide the highest

performance in terms of accuracy, recall, precision, F1 score, and AUC. The multiclass classification model was already published in an international journal. One submitted article proposing binary classification is under the review process. Two manuscripts on binary classification and multiclass classification are now prepared for submission by the end of this year.

For the modification of WOD, the Optimized Weighted Objective Distance (OWOD) is proposed. The concept of OWOD is the combination of knowledge-based and data-driven evidence for constructing more personalized individual health measurement. The classification using WOD was compared to other existing machine learning-based methods with feature engineering methods. The results show that the classification using WOD outperformed some methods, including Fast Forest OVA, Gradient Boosted Tree, Decision Tree, and SVM. The manuscript is now in preparation for submission by the end of this year.

Conclusion:

This study proposes the machine learning-based method and the modified objective distance to create a classification model for elderly people with dementia risk. The data from regular health checks is collected from the hospitals in the upper north of Thailand over the last 5 years for model construction. Several machine learning-based models are constructed, and the classification performances are compared. The models are expected to be created based on minimum 10,000 data records to provide the most effective classification model.

Current Output:

1. One Publication: Yongcharoenchaiyasit, K., Arwatchananukul, S., Temdee, P., & Prasad, R. (2023). Gradient Boosting Based Model for Elderly Heart Failure, Aortic Stenosis, and Dementia Classification. IEEE Access.
2. Two master students and two Ph.D. students.

Challenges/Problems and Possible solutions:

Data pre-processing of raw data collected from different hospitals, which is kept in different formats.

Future plan:

1. To test OWOD with different sizes of dataset.
2. To compare the performance of classification models with deep learning methods.

Artificial Intelligence and Machine Learning for Forecast of Nanoparticle Concentrations in Southern Thailand from Local and Transboundary Sources and Model to Assess Economic Loss due to Health Effects

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Project duration: 3 years, from 1 April 2023 to 31 March 2026
Current progress: 52%

Abstract:

Current air quality forecasting has been limited to $PM_{2.5}$ mostly using WRF-Chem model. Ultrafine particles or $PM_{0.1}$ are known to have strong impact on human health and no studies have been dedicated to ultrafine particle forecast to date. AI/Deep Learning and remote sensing are used to study and reliable forecast models are expected in this program. Progress during the first 6 months includes design of a central platform for future forecasting. $PM_{0.1}$ - $PM_{2.5}$ are sampled in all locations. PM concentrations were obtained while the chemical properties are undergoing analysis. LSTM at lag 4 was initially found to be a suitable deep learning model for particle forecast. The Extra Trees Classifier and Random Forest Classifier models are good for fire risk forecasting in KK-PSF. Model for economic impact from ultrafine particles are under development. Acquired health data were collected and cleaned.

Rationales/Problem statements:

Air quality forecasting has been limited mostly to the Weather Research Forecast - Chemistry (WRF-Chem) model for $PM_{2.5}$. Recent advancement of AI, computing technology, data science, and remote sensing can play a big role in air quality forecasting, especially fine or ultrafine particles. Ultrafine particles or $PM_{0.1}$ are known to have strong impact on human health. This includes the respiratory and cardiovascular diseases. There are no studies on the ultrafine particle forecast to date. AI/Deep Learning and remote sensing can increase accuracy of the forecast models. In addition, development of economic model for treatment of patients as a result of exposure to ultrafine as well as fine particles can lead to an effective decision for policymakers in setting priorities for national budget allocation.

Objectives:

1. To analyze physical and chemical characteristics of $PM_{0.1}$ in different regions in southern Thailand to obtain empircal model to evaluate $PM_{0.1}$ from largely available $PM_{2.5}$.
2. To develop a $PM_{0.1}$ forecast model for southern Thailand using deep learning.
3. To develop a $PM_{0.1}$ forecast model from KK-PSF fire using RS and ML.
4. To develop a health economic model as a result of $PM_{2.5}$ and $PM_{0.1}$.
5. To develop high capability HR with relevant expertise.

Progress/Findings/Results:

Development of central platform for the forecast of $PM_{0.1}$ and $PM_{2.5}$

The central platform has been designed to integrate results from all projects together. It includes fire hotspots, air pollution, and meteolorogical data. Structure of the platform contains sources, ETL, data store and API.

Physical and chemical characteristics of $PM_{0.1}$ and $PM_{2.5}$ in southern Thailand

Air samples were collected during May-Aug 2023 in Songkhla, Surat Thani, and Phuket. $PM_{2.5}$ at Songkhla station was found to be highest while $PM_{0.1}$ concentration in Surat Thani was 2 times as high as in Songkhla and Phuket. Ratios of $PM_{0.1}$ to $PM_{2.5}$ was 8-16%.

Chemical components in PM are undergoing analysis. Empirical model to evaluate $PM_{0.1}$ from $PM_{2.5}$ will be developed after samplings are done for a year.

Deep learning model for the forecast of $PM_{0.1}$, PM_1 and $PM_{2.5}$.

After using data of $PM_{0.1}$ and $PM_{2.5}$ acquired from the research team during 8 Jan 2016 to 31 Dec 2022 to construct a model for forecast, it was found that LSTM method at lag 4 could provide best forecast results for all particle sizes. Accuracy of LSTM method will be improved in the next step when algorithm testing is conducted for other forecasting. Data of air pollution during Jan 2016 to Aug 2022 will be used for Exploratory Data Analysis.

Fire risk map in KK-PSF from forecast using machine learning

Ground data and GIS data including 17 factors relevant to risk of forest fires in the past 7 years were collected. Results from fire risk analysis in KK-PSF using Fuzzy Analytic Hierarchy Process (FAHP) were separately obtained for El Niño and La Niña years. In El Niño years, most of the fires were found in the middle and upper part of the PSF. Areas where the risk was high and very high took 52% of the total area. During the La Niña year, most of the area was in low to moderate risk. The Extra Trees Classifier and Random Forest Classifier models for fire risk forecast showed accuracy between 0.9027-0.9145 for the trained data, while accuracy for the test data still needs an improvement.

Model for health risk forecast and economic impact from fine particles.

Results include

1. Meetings with relevant organizations to define premature deaths, handle mortality and air pollution data, and define diseases from ICD-10 for analysis of diseases.
2. Acquisition of relevant data and they are stored in the workstation.
3. Management of death and premature death data for analysis along with air pollution. Data were cleaned by text mining, stemming and tokenization before used for deep analysis.
4. Management of air pollution data by acquiring data from PCD stations in southern Thailand. The data were prepared for next analysis including imputation and interpolation.

Conclusion:

Progress of the research program during the first 6 months follows the original plan. The central platform has been designed. $PM_{0.1}$ - $PM_{2.5}$ are sampled in all locations. PM concentrations were obtained while the chemical properties are being analyzed. LSTM at lag 4 was initially found to be a suitable deep learning model for particle forecast. Extra Trees Classifier and Random Forest Classifier models are good for fire risk forecasting in KK-PSF. Model for economic impact from ultrafine particles are under development. Acquired health data were collected and cleaned.

Current Output:

- 4 Manuscripts are under drafting
- 1 PhD student/6 Master's students/10 undergrad students
- LSTM algorithm for particle forecast model
- Health database related to mortality related to air pollution
- 1 research center (Air Pollution and Health Effect Research Center)

Challenges/Problems and Possible solutions:

This research program is the first attempt in SEA to develop forecast models for $PM_{0.1}$. The main challenge is to prove the outcome is reliable. It depends on several factors. The first factor is sufficient ground data of $PM_{0.1}$ for verification. Since we have collected the data for more than 5 years, and expanded locations in this program, it is a good starting point. Capability of the research team is vital. We have built a multi-disciplinary team in which experts from several disciplines work together. Our team spirit and determination will bring us success.

Future plan:

Because we could follow the plan in the first 6 months without major obstacles, the future plan should follow the initial plan.

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ด้าน Global Partnerships (Materials, Battery, Energy)

High-Quality Manpower and Institutional Development through Collaboration on Innovative Bioresources in Biorefinery, Metabolomics of Natural Products, and Materials for Sustainability

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Project duration: 3 Years, from 1 November 2022 to 31 October 2024

Current progress: 66%

Abstract: The strong partnership in the project aims to advance cutting-edge research in bioresources, which includes three areas: innovative chemistry for biorefinery, metabolomics and bioactive natural products, and innovative materials for sustainable environment. In biorefinery, the calcium-manganese(IV) oxide catalyst supported on porous materials for the selective oxidation of HMF to FDCA in water as a green solvent and oxygen as a green oxidant was discovered. In metabolomics, mass spectroscopy-based analysis of *Ventilago harmandiana* Pierre, *Garcinia speciosa* Wall., and *Ganoderma lucidum* was performed. A web-based approach to develop the mass spectrum web application is currently underway. In addition, the application of Q-TOF-MS/MS-based metabolomics on 5 alpha reductase inhibitors from teak leaf extracts have been demonstrated. In materials, a new composite based on COF and $Ti_3C_2T_x$ MXene is in progress under collaboration with the Taiwan members. CO_2 electroreduction catalyst for hydrogen generation were also studied, yielding new insights into hydrogen production.

Rationales/Problem statements: In this project, the scheme for scientific partnership entitled " High- Quality Manpower and Institutional Development through Collaboration on Innovative Bioresources in Biorefinery, Metabolomics of Natural Products, and Materials for Sustainability" extends the breadth and depth of the research areas under investigation. The well-balanced network of researchers involved consists of first-rate expertise appropriate to drive a coherent effort to address the demanding research program. The collaborative program emphasizes on cutting- edge technologies required to advance the field and to compete internationally. The project consists of members from at least three universities in Thailand and two institutions in Taiwan. Moreover, the project will enhance activities of existing collaboration among the three Thai universities. The research program includes three major subprojects as follows: (1) Innovative Chemistry for Biorefinery, (2) Metabolomics and Bioactive Natural Products, and (3) Innovative Materials for Sustainable Environment.

Objectives:

1. To initiate a rigorous network of high-quality researchers between Mahidol University, Naresuan University, and Ubon Ratchathani University in Thailand and Academia Sinica and National Tsing Hua University in Taiwan.
2. To foster well-engaged collaborations on specific research topics that address bioresources.
3. To prepare imminent scientific leaders and highly skilled graduate workforce with solid theoretical backgrounds and practical experience through research visits and scientific meetings.
4. To increase the number of high-quality publications, citations, and patents.

Progress/Findings/Results: *Innovative Chemistry for Biorefinery:* In the past 24 months, we have synthesized calcium-manganese (IV) oxide (Ca-MnO_2) supported on porous materials as non-noble metal catalysts for the selective oxidation of HMF to FDCA in water as a green solvent and oxygen as a green oxidant. Ca-MnO_2 catalysts exhibited excellent conversion of HMF and high yield of FDCA. The preliminary results here revealed the opportunity for further development of this catalytic system. *Metabolomics and Bioactive Natural Products:* mass spectroscopy-based analysis of *Ventilago harmandiana* Pierre, *Garcinia speciosa* Wall., and *Ganoderma lucidum* was performed. A web-based approach to develop the mass spectrum web application is currently underway. Additionally, further isolation and structure elucidation of the stem bark of *Ventilago harmandiana* Pierre led to the identification of novel pyranonapthoquinones and napthoquinones. Subsequently, we have continued to delineate the PNQ biosynthesis pathway based on MS/MS fragmentation mechanism to investigate the biosynthetic pathway of PNQ-318A, which exhibited the highest anti-inflammatory activity. In parallel, we started RNA analysis of different parts of *Ventilago harmandiana* Pierre in which the integrative analysis of the transcriptomic and metabolomic data will be performed to elucidate the proposed biosynthetic pathways. Furthermore, we initiated a novel approach based on quantum chemistry calculations to extend the coverage of metabolite identification. In addition, the application of Q-TOF-MS/MS-based metabolomics on seeking and identifying 5 alpha reductase inhibitors from teak leaf extracts have been demonstrated. *Innovative Materials for Sustainable Environment:* Our team discovered a new, eco-friendly way of using solution plasma to prepare a nanocomposite between graphene oxide and manganese dioxide for energy storage application as well as a new nontoxic solvent system based on sulfolane for efficient fabrication of photovolatics. In addition, the carbon-based $Ti_3C_2T_x$/g-C_3N_4 composite was also found to demonstrate favorable performance for energy storage application. Another composite based on COF and $Ti_3C_2T_x$ MXene is in progress under collaboration with Taiwan members. Our team also deciphered the reaction mechanism of HCOOH dehydrogenation over a single Pd atom incorporated nitrogen-doped monovacancy defective graphene (Pd-N3Gr). Using the first-principle density functional theory (DFT), the catalytic performance of Pd-N3Gr was also evaluated and compared with some of other Pd-based catalysts. In addition, a binder-free Cu-Co cathode catalyst for Li-CO_2 battery and CO_2 electroreduction catalyst for hydrogen generation were also studied.

Conclusion: The first 24 months of the project marked a strong start of research activities that would serve as a fundamental basis for collaboration. the current and future young researchers will be trained at highest quality on interdisciplinary, cutting-edge research in bioresources. Fifteen young researchers (6 postdoctoral, 4 Ph.D., 4 M.Sc., and 1 B.Sc. levels) already engaged in the project. Many more young researchers are in the process of collaborating in the project.

Challenges/Problems and Possible solutions: The challenges encountered are mostly experimental in nature, which, so far, could be resolved by the collaboration among project members.

Future plan: A significantly larger number of researcher exchange activities will be accelerated to promote research collaboration and achieve the goals of the project.

Comparative Photocatalyst Deactivation in Liquid Phase Using Different Coating Technique: Sputtering and Wet Chemistry

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Project duration: 3 year, from 1 November 2021 to 31 October 2024
Current progress: 75%

Abstract:

Deposition of AgO on TiO_2 films are synthesized by using magnetron sputtering and condensation methods. Effect of sputtering time, equipment setup and loading amount on the physiochemical and photocatalytic activity are investigated for both methods. Both deposited films exhibited high dispersion of AgO particles on the surface of TiO_2 films and higher photocatalytic activity compared with undoped one. Loading with 10 μg by condensation method and 10 seconds sputtering are the best loading condition of both methods, respectively. In order to test the stability of photocatalyst films, both samples are used repeatedly for 10 cycles. Both films start to deactivate after 5 cycles. Leaching of the AgO of condensation- and Si bonding for sputtering-made film is the main reason for the deactivation of the films.

Rationales/Problem statements:

Using of organic dyes in industrial is one of the most important sectors in Thailand. These industries release a lot of wastewaters containing dye-polluted effluents that are harmful to living organism. Therefore, the waste water needs to be treated.

The photocatalytic process is considered one of the most promising techniques in the field of environmental protection. Among all photocatalysts, TiO_2 possesses the most potential due to its high stability, non-toxicity, and high photocatalytic properties. However, there are some disadvantages of the use of TiO_2 particles in liquid phase photocatalysis due to its fine particle size, the removal of which is difficult after process. Furthermore, TiO_2 had high bandgap and cannot use under visible light irradiation

In order to overcome these problems, depositing of photocatalyst on plastic film is one the best solutions and doping the TiO_2 film with AgO particles can decrease the bandgap energy and improve the photocatalytic activity.

Objectives:

To study and compare the catalyst deactivation of photocatalyst deposited on plastic film prepared by sputtering and wet chemistry techniques

Progress/Findings/Results:

AgO nanoparticles, formed on the surface of the PET-anatase TiO_2 film prepared from sputtering and condensation method, can be successfully obtained. The SEM indicated that the average agglomerated particle size of the catalyst on the thin films is approximately 50–100 nm. The Ag^+ ions will, therefore, spread evenly on TiO_2 nanoparticles during the

deposition process. NB was selected as a suitable contaminant to evaluate the photocatalytic degradation performance of as-prepared samples. The degradation of NB by PET-Anatase under light illumination was 75% during 100 min of experiment. However, the coating of 10 µg Ag enhanced the photocatalytic degradation rate of NB (96%). In addition, when the Ag sputtering time extended to 10 second without any mesh, the film had the most photocatalytic activity. The %degradation of PET-Anatase/10SAg and PET-Anatase were 99% and 66%, respectively. For both types of films including condensation and sputtering, the photocatalytic activities were improved with the initial increase in AgO amount. The photocatalytic activity of condensation method was higher than sputtering method for the optimum conditions.

AgO is a p-type semiconductor with band gap of 1.7 eV, and TiO_2-Anatase is an n-type semiconductor with band gap of 3.2 eV; when these two semiconductors come into contact, they form a p-n heterojunction. TiO_2 electrons will transfer to AgO until thermal equilibrium is reached. Consequently, TiO_2 becomes positively charged while AgO becomes negatively charged, causing an electric field to form at the junction. The excited electrons in the AgO could directly reduce the NB or reduce the dissolved oxygen to produce superoxide which could degrade NB. Additionally, the electric field could draw electrons to the CB of TiO_2, where NB reduction and superoxide formation could occur. Furthermore, the holes could be transferred to the VB of AgO. Oxidation of water on the VB of AgO may provide the electrons required for the NB degradation process. While AgO could increase the photocatalytic activity. However, high amount of AgO could cover the film and reduce the catalyst's access to the reactant, thereby decreasing the catalyst's activity.

To reach one of our main goals in this research, the reusability of the films was examined in the related optimum conditions for 10 cycles. The yield of reaction decreased to 23% while it was almost 24% for the condensation method. Due to the low concentration and high dispersion of Ag and Ti in the films prepared by the condensation method, we could not measure the differences in their concentrations in the EDX analysis. However, we observed a significant decrease in the concentration of Ag in the film prepared by the sputtering method, suggesting that the decrease in the catalyst's activity was due to the detachment of Ag from the film. Additionally, we analyzed the surface composition of the elements in both films using XPS. For the film synthesized by the condensation method, we observed a significant decrease in the concentration of Si after 10 batches of experiments. Considering the role of Si as a binder for attaching the catalyst to the PET substrate, this suggests that the catalyst leached from the film, resulting in a decrease in its activity. Moreover, the surface concentration of Ag in the film synthesized by the sputtering method decreased substantially. Therefore, the leaching of the catalyst is likely the main reason for the deactivation of the films.

Conclusion:

Deposition of AgO nanoparticle on TiO_2 films have successfully been synthesized by magnetron sputtering and condensation methods. Both deposited films gave a well dispersion of AgO particles and higher photocatalytic activity compared with undoped one under visible light irradiation. Loading with 10 µg by condensation method and 10 seconds sputtering are the best loading condition of both methods, respectively. To test photocatalyst films stability, both samples are used repeatedly for 10 cycles. Both films start to deactivate after 5 cycles. Leaching of the AgO of condensation- and Si bonding for sputtering-made film are the main reason for the photocatalyst deactivation.

Current Output:

12 International papers

Challenges/Problems and Possible solutions: -

Future plan:

The work in next step is tried to investigate more about the photocatalytic reaction mechanism and catalyst deactivation process in order to make clear understanding of the effect of deposition methods on overall processes. We also try to expand the collaboration with other two international laboratories to find the new opportunities to make new research projects.

Advanced Catalytic Technologies for Sustainable Utilization of Oil Palm Empty Fruit Bunch

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Project duration: 3 years, from 1 April 2023 to 31 March 2026

Current progress: 25%

Abstract:

This project is a part of the collaborative research project "Advanced Catalytic Technology for Sustainable Utilization of Oil Palm Empty Fruit Bunch" or ACT-PEFB under The East Asia Science and Innovation Area Joint Research Program (e-ASIA JRP), which consists of principal investigators from 3 countries: Associate Professor Toshiyuki Yokoi (Tokyo Institute of Technology, Japan), Professor Chawalit Ngamcharussrivichai (Chulalongkorn University, Thailand) and Professor Marlon T. Conato (University of the Philippines–Diliman, Philippines). The project aims to develop advanced catalytic technologies for sustainable utilization of PEFB as feedstock for production of biofuels and high-value chemicals. Our strategy for ACT-PEFB project is to design and synthesize highly active, selective, and stable heterogeneous catalysts based on the reaction mechanism. We expect that our achievement will contribute to the creation of international research networking and encouragement of young researchers as well as the achievement of SDG through carbon recycling by sustainable utilization of PEFB.

Rationales/Problem statements:

Aviation industry is one of the industries that generates a large amount of carbon dioxide (CO_2), accounting for 12% of the total transport sector. Therefore, the International Civil Aviation Organization (ICAO) has announced regulations to reduce CO_2 from international aviation, one of which is to use Sustainable Aviation Fuels (SAF) or bio-jet fuels produced from ICAO certified processes. Palm oil is a potential vegetable oil as renewable feedstock for SAF production through commercial Hydroprocessed Esters and Fatty Acids (HEFA) process. An increasing demand of SAF is expected to result in a shortage of oil feedstock in the future. Oil palm empty fruit bunch (PEFB) is an agricultural waste generated around 0.3 million ton each year during the production of palm oil. PEFB consists of 33.2–43.5 % cellulose, 11.7– 23.6 % hemicellulose, and 21.3–24.0 % lignin. It has been considered as a good lignocellulose feedstock to produce second-generation biofuels, as well as a wide range of high-value products. Consequently, the utilization of PEFB for production of hydrocarbon compounds not only secures the supplies of renewable feedstock for SAF production but also increases the value chain of palm oil industry through this sustainable strategy.

Objectives:

1. Develop bifunctional catalysts for conversion of PEFB-derived lignin into hydrocarbon components of SAF

2. Develop prototype technologies for producing SAF from PEFB
3. Nurture young researchers with expertise in catalyst technology and biomass valorization towards biofuels

Progress/Findings/Results:

In this collaborative research project, palm oil and PEFB-derived waste oil were converted into paraffins as main components of SAF by the Philippines team, while the Thailand team focuses on valorization of PEFB-derived lignin to cycloparaffins and aromatics, as well as other biochemicals, such as phenolic and cyclic ketone compounds via hydrodeoxygenation (HDO) processes. Raw PEFB (13–15 % lignin content) was dried and milled to reduce its size smaller than 2 mm, followed by separation of lignocellulose components using dilute acid solution in a 5-L glass reactor, yielding the lignin with >80% purity. The PEFB-derived holocellulose will be further upgraded to fuel additives by the Japan team. The depolymerization of PEFB and lignin extracts was investigated by thermogravimetric analysis. To develop efficient and economic catalysts for HDO, nickel (Ni) was used as a main active metal that was loaded on different oxide supports using impregnation method. The resulting bifunctional catalysts were characterized by various techniques to elucidate their physicochemical properties. The HDO performance of prepared catalysts was evaluated using single and binary phenolic-lignin model compounds, such as guaiacol and cresols. The substrate conversion and product selectivity were calculated based on gas chromatography (GC) and GC-Mass spectrometry.

Conclusion:

The prepared bifunctional catalysts exhibited a good dispersion of Ni phases. showed nearly complete conversion of phenolic-lignin model compounds. The product selectivity was determined by the physicochemical properties of the catalysts, and also altered by adjusting the operating conditions.

Current Output:

2 Manuscripts are under preparation.

Challenges/Problems and Possible solutions: -

Future plan:

The depolymerization behavior of PEFB and lignin extracts was further investigated by pyrolysis-GC/MS. The effects of catalysts addition on the depolymerization will be studied. PEFB will be pyrolyzed to obtain bio-oil as real biomass feedstock in HDO catalyzed by the developed bifunctional catalysts.

Enhancing Organic Synthesis, Contaminant Detections, and Geographical Indication by Advanced Technologies in Ambient Ionization with Mass Spectrometry

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Project duration: 3 year, from 1 November 2021 to 31 October 2024
Current progress: 54%

Abstract:
This project aims to integrate mass spectrometry which is a sensitive and universal technique and ambient ionization technique which does not require complicated sample preparation to solve various problems including enhancement of the efficiency of organic synthesis under microdroplet-assisted conditions, rapid analysis of food and environmental contaminants, and identification of geographical indication in Thai agricultural products. Achievements in the past two years include the fabrication of reactor prototypes to perform reactions under microdroplet conditions, the evaluation of selected reactions under the microdroplet conditions in comparison with bulk solution, the application of the electrospray technique for the preparation of high-performance SERS substrates, the development of paper-based sensors for analysis of meat spoilage, as well as the use of ambient ionization and chemometrics to solve various problems including the identification weedy rice contamination, melon seeds varieties, and geographic indication of Thai agricultural products including coffee, pineapple and durian.

Rationales/Problem statements:
Mass spectrometry is a highly sensitive and universal technique that can be applied to practically all chemicals since it detects the mass-to-charge ratio, which is an intrinsic property of any compound. The technique has been a gold standard for analytical purposes in many applications, but the process is complicated and requires expensive instruments as well as highly trained personnel. The ambient ionization technique can solve the aforementioned problems by not only simplifying the sample preparation but also adding other functions such as selective enrichment or pre-separation. The combination of the two techniques can be applied not only in the analytical fields but also enables rapid discovery or improving efficiencies of new chemical reactions.

Objectives:
- To develop a system for microdroplet-assisted synthesis and its applications in rapid and value-added chemical synthesis
- To integrate knowledges on chemical functionalization of papers and paper spray mass spectrometry for the detection of food and environmental contaminants
- To integrate knowledges on mass spectrometry and chemometrics for the discovery of geographical indication markers in Thai agricultural products

Progress/Findings/Results:
The work is divided into three subprojects. The first subproject involves the development of a system for microdroplet-assisted synthesis and its applications in rapid and value-added chemical synthesis. Two prototypes of reactors under microdroplet conditions were designed and constructed. Several reactions have been studied under the microdroplet conditions in comparison with the bulk solution. These include the synthesis of cannabidiol derivatives, the deuteration of organic compounds by hydrogen-deuterium exchange and halogen-

deuterium exchange conditions, the synthesis of Betti's base, and the formation of cyclopentenones from the reaction between furfural and amines. The latter reaction shows remarkably improved efficiency and product selectivity under the microdroplet conditions when compared to the bulk solution phase. This reaction was thus selected for further in-depth investigation. In addition, an advanced ambient focusing ion funnel-assisted electrospray deposition technique was developed and applied for the fabrication of SERS substrates bearing uniform gold nanospheres and gold-nanorods coatings. The substrates prepared by this method showed 70- and 20-fold improved performance when compared to traditional drop-casting and electrospray deposition techniques.

The second subproject involves the use of chemically functionalized papers and paper spray mass spectrometry for the detection of food and environmental contaminants. A paper-based sensor array bearing a diverse set of fluorescence cyanostilbene probes was successfully fabricated. It has been successfully applied for the optical detection of biogenic amines generated during meat spoilage. In another work under this subproject, a general design of a colorimetric sensor that employs peptide nucleic acid (PNA) in combination with DNA aptamer for the detection of various target analytes was proposed. The detection principle relies on the aggregation of gold nanoparticles induced by the PNA probe released upon binding of the aptamer to its target analyte (THC and progesterone). The proof-of-concept experiments in the solution phase demonstrated good selectivity and sensitivity. The aptamer-based sensor is currently being developed into a paper-based format.

The last subproject integrates knowledge of mass spectrometry and chemometrics for the discovery of geographical indication markers in Thai agricultural products. Selected agricultural products with different geographical origins with a statistically significant number of samples were collected and analyzed by DART-MS and/or PS-MS in combination and/or comparison with conventional techniques such as HPLC or NIR. Chemometric techniques were applied to cluster the results into groups and find correlations with the specific nature of the samples or their geographical origins. Applications have been showcased in the detection of weedy rice seed contamination, the identification of melon seed varieties, and the identification of geographic indication in coffee, pineapple, and durian. The results demonstrated the feasibility of these techniques to provide a rapid chemical fingerprint of agricultural products that can correlate to their specific varieties or geographical origins.

Conclusion:

In conclusion, the combination of ambient ionization techniques and mass spectrometry offers a powerful way to discover new reactions or to improve the efficiency of conventional synthesis. Together with chemometrics, it also provides a simple and rapid means for the detection of various chemical entities including food and environmental contaminants.

Current Output:

1) Dhinakaran, M.K.; Smith, B.L.; Vilaivan, T.; Maher, S.; Praneenararat, T. Cyanostilbene-based fluorescent paper array for monitoring fish and meat freshness via amino content detection. *Microchim. Acta* **2023**, *190*, 215.

2) Pumbua, R.; Sricharoen, N.; Wongravee, K.; Praneenararat, T. Paper spray mass spectrometry as an effective tool for differentiating coffees based on their geographical origins. *Food Chemistry: X* **2023**, *18*, 100624.

3) Makmuang, S.; Terdwongworakul, A.; Vilaivan, T.; Maher, S.; Ekgasit, S.; Wongravee, K. Mapping hyperspectral NIR images using supervised self-organizing maps: Discrimination of weedy rice seeds. *Microchem J.* **2023**, *190*, 108599.

4) Akbali, B.; Boisdon, C.; Smith, B.L.; Chaisrikhwun, B.; Wongravee, K.; Vilaivan, T.; Lima, C.; Huang, C.-H.; Chen, T.-Y.; Goodacre, R.; Maher, S. Focusing ion funnel-assisted

ambient electrospray enables high-density and uniform deposition of non-spherical gold nanoparticles for highly sensitive surface-enhanced Raman scattering. *Analyst* **2023**, *148*, 4677–4687.

Challenges/Problems and Possible solutions:

The delay of budget transfer, and the lack of direct research budget for international collaborators.

Future plan:

Continue according to the plan indicated in the proposal with the aim to achieve 9 Q1 publications and two submitted patent applications as promised.

Development of Reinforcing Materials in Concrete by Natural Fiber Bars

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 60%

Abstract:

In the initial two years, a dual focus was pursued: research endeavors and network development. In this research, fibers were extracted through alkali treatment, the properties of the fibers were improved through DBD plasma treatment and incorporated into composite materials to enhance their mechanical properties. High-strength reinforced fiber bars were crafted. Concurrently, a robust research network was fostered by the project through domestic and international collaborative events, researcher exchanges, project progressive meetings, and international symposiums. Achievements in the past 24 months include two international journal publications, a fiber extraction method, a high-strength fiber-reinforced bar (HSFB) prototype, an HSFB production process, and progress in networking activities, constituting a 65% completion of the overall project plan.

Rationales/Problem statements:

Considered a vital cornerstone of the construction and real estate sector, the construction material industry accounts for up to 60 percent of the construction value. A market share of approximately 21 percent is held by construction steel, encompassing reinforcing bars and structural steel shapes. However, due to the absence of a primary steel industry in Thailand, raw steel materials must be imported, resulting in increased production costs and steel prices. These prices are heavily influenced by global market fluctuations. Consequently, various alternative materials are being introduced to replace steel in the construction material industry. In response to this situation, the importance of developing alternative materials to replace conventional steel in reinforcing concrete is recognized by the research team. Natural materials serving as substitutes are sought to reduce transportation costs and provide an alternative construction material, benefiting the construction industry, small-scale businesses, and communities economically and socially.

Objectives:

1. To develop researchers and foster collaboration networks between Thai and Korean .
2. To study and develop the extraction process as well as the characteristics of fibers from non-wood materials.
3. To investigate and develop the composite structure of concrete using non-wood fibers and polymer.

4.To study and develop high-strength fiber-reinforced bars for application in reinforced concrete.

Progress/Findings/Results:

In the second phase of the project, the emphasis will be placed on the creation of HSFB prototypes that involve the incorporation of fibers that have been extracted and enhanced through the plasma technology developed in the first year shaping of these fibers with epoxy to produce a composite material akin to steel bars will be undertaken with properties closely resembling those of steel bars. These prototypes will be subjected to testing for actual utilization in concrete applications. The suitability of these prototypes for practical use in concrete, encompassing the application of the HSFB model, was determined through testing. For the networking activities, the following initiatives have been undertaken by the project:

- **Networking Progressive Meeting:** Progress tracking, activity reporting and discussions on future research directions were conducted through monthly meetings.
- **International/National Research Exchange:** Research exchange activities between Thai and Korean researchers, both within Thailand and the Republic of Korea, were facilitated. Visits and collaborative discussions with leading Korean universities.
- **International Symposium:** In this second year, two International Symposiums have been successfully organized by the project. "The International Symposium on Sustainable Healthcare Innovation for Future Society" was held in collaboration with KAIST, and "International Advanced Materials & Energy Technology Collaboration Symposium 2023" was organized in collaboration with SKKU and Korea Aerospace University.
- **Participation in Conference from the Network**
  Two researchers in this project had an oral presentation at the 13th Asian-European International Conference on Plasma Surface Engineering, Republic of Korea.

Conclusion:

Over the last 24 months, the project has primarily focused on developing HSFB prototypes for concrete use and conducting actual tests. Activities to establish a research network, both nationally and internationally, were also undertaken. The project has successfully achieved 60 percent of its overall goals outlined in the plan. This includes the development and successful testing of HSFB prototypes for concrete applications. This success propels the project into the next phase, involving process standardization, product certification, market evaluation, feasibility studies, and technology commercialization. These activities are scheduled for implementation in the project's third year.

Current Output:

2 Journal publications (Q1), 1 Production of cellulose extraction, 1 Production of HSFB, 1 Prototype of HSFB, 1 Production of HSFC, 1 Prototype of HSFC and 1 International networking

Challenges/Problems and Possible solutions:

The number of journal publications that must be submitted in the second year for three papers is still behind schedule. and cannot be submitted in the second year. We have made adjustments to the manuscript of the paper that must be submitted in parallel with the third-year project activities.

Future plan:

1. Process Standardization and Product Certification
   To submit documentation for certification to a standard of reinforced fiber bars.
2. Market Evaluation and Feasibility Study
   To evaluate market data and business feasibility information to produce reinforced fiber bars for the construction industry.
3. Technology Commercialization

To develop commercialization plan for the technology and present it through various channels, such as academic exhibitions, in no fewer than one event.

Nover Energy Scavenging Technology

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Project duration: 3 years, from 1/April/2023 to 31/March/2026
Current progress: 40 %
Abstract: This work, we intend to realize next generation energy harvesting devices using photovoltaics-thermoelectric (PV-TE). Specifically, thin film photovoltaics will be utilized to harvest a portion of the spectrum from the incoming sunlight. Thermoelectric materials will be integrated beneath the thin film PV to harvest the remaining part of the spectrum lost to heat. The proposed work will tap on the combined research capabilities of the teams from Singapore, Thailand, and Myanmar. This includes the Singapore team's existing works on high performance thermoelectric materials, while Thailand's group has manufactured TE generators from bulk materials to support this project and generated abundant datasets of their electrical power performances. The Thailand and Myanmar group have also collaborated on combined experimental-theoretical studies to improve perovskite solar cell, leveraging on the Myanmar team's expertise in photovoltaics. The success of this proposal will pave the ways for easy preparation of high efficiency devices for applications.

Rationales/Problem statements:

For decades, photovoltaics and thermoelectric have been running at the forefront of green energy production. Nevertheless, while photovoltaics can harvest light into electricity, they only contribute slightly over 2% to the world's electricity due to high cost of manufacturing. Likewise, while thermoelectric have the dual function of waste heat energy harvesting and solid-state cooling, they are limited to niche applications where costs are not critical. The key hindrance preventing the widespread adoption of both photovoltaics and thermoelectric is the limited efficiency and tedious manufacturing, resulting in high cost per unit energy generated. I This is both a materials challenge and an engineering challenge. In this work, we focus on fabricate generation energy harvesting devices using PV-TE to high efficiency and versatile energy harvesting devices for a wide range of applications.

Objectives:

1. To design and fabricate photovoltaic and thermoelectric prototype
2. To fabricated and testing PV-TE performance prototype together with Singapore and Myanmar country
3. To development and testing PV-TE performance more than 25% together with

Singapore and Myanmar country
4. To applying PV-TE with low-power electronic devices and publication

Progress/Findings/Results:

A research team from Sakon Nakhon Rajabhat University Thailand, were design and fabricated PV and TE prototype by using Finite element analysis, spin coating, and meth soldering methods. These findings result of simulation electrical power, output power, heat transfer, and flow rate of TE generator were investigated. The performance of TE and PV prototype revealed that the voltage as a function of temperature. The maximum output voltage and electrical power is 3.24 V and 5.23 W at temperature different of 200 ºC. The total current density value is uniformly distributed within *p-n* TE materials. The output voltage and electrical power obtained are consistent with increasing temperature difference. After that test TE prototype compare with a commercial by using direct heating and water flow as a heat sink, T_c = 0, T_h = 120 ºC for TE prototype and T_c = 0, T_h = 140 ºC for a commercial. The maximum V_{oc} of TE prototype is 3 V, and the TE commercial is 5.4 V at temperature difference of 120 ºC and 140 ºC. The maximum P_{oc} value of the TE prototype is 1.4 W and the TE commercial is 2.2 W at the temperature difference of 102 ºC and 97 ºC, which have similar values at the same temperature. They also tested the PV prototypes. It was found that PV cell size 5 x 5 cm^2 highest electric power is 141.774 mW, the fill factor is 54.36%, the current density per square centimeter is 23.6793, the highest efficiency is 11.65%, and PV cell size 2.5 x 2.5 cm^2 light intensity 100 mW cm^2, temperature 25 °C, open circuit voltage 1.025437 V, closed circuit current 2.13113 mA, fill factor 72.44%, current density per square centimeter is 23.6793, will have the highest efficiency at 18.09%, respectively. The PV and TE prototype discovery data showed positive results and will lead to the manufacture of the PV-TE prototype in the next report.

Conclusion:

In conclusion, we designed and fabricated PV and TE module by using spin coating, Finite element analysis (ANSYS program) and melt soldering methods. The electrical properties of TE and conversion efficiency of PV were investigated. We have succeeded in making a PV prototype (perovskite) with an efficiency of approximately 18.09% and the TE prototype has a maximum voltage of 3V with a temperature difference of 120 ºC, the potential impact: Wrap up the introduction by discussing the potential impact of PV-TE on renewable energy generation and its contribution to a more sustainable future.

Current Output:

1. Photovoltaic prototype (perovskite solar cell)
2. Thermoelectric prototype

Challenges/Problems and Possible solutions:

Challenges/Problems:

1. The advanced analytical tools of the Sakanok Rajabhat University of, Thailand, University of Mandalay, Myanmar and the National University of Singapore, Singapore Country are not sufficient, so the networks in other countries need to be relying.

Possible Solutions:

1. The samples were sent to the Institute of Advanced Industrial Science and Technology (AIST), Department of Materials and Chemistry of the Japan Institute of Nanomaterials Research. For measurement and analysis of thermal properties of thermoelectric.
2. The researchers will conduct short-term research, measured and analyzed the optical properties with NANOTEC (NSTDA), to inventing a perovskite solar cell prototype.

Future plan:

1. PV-TE prototype: TE materials will be integrated beneath the thin film PV to harvest the remaining part of the spectrum lost to heat.
2. Test the efficiency of PV-TE prototype: this efficiency analysis contributes to the broader understanding of thermoelectric materials and their potential applications in clean energy technologies.

The successful application of the integrated PV-TE energy harveting materials will realistically enable their translation into real-world applications, creating societal impact.

Data-driven Computational Design of High-performance Thermoelectric in Atomic Layers and Topological Materials

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Project duration: 3 year, from 1 April 2022 to 31 March 2025

Current progress: 60 %

Abstract: This study explores the data-driven computational design of high-efficiency thermoelectric materials, concentrating on atomic-layered topological structures, specifically SnSe/$SnSe_2$. The research centers on synthesizing these materials using thin film sputtering and liquid-phase exfoliation techniques. Employing computational models, the study predicts and optimizes the thermoelectric properties of SnSe/$SnSe_2$, guiding the fabrication process. Thin film sputtering ensures precise layer control, while liquid-phase exfoliation enables the extraction of ultra-thin layers. Experimental validation of the computational predictions and thorough characterization reveal the interplay between structure and thermoelectric performance. The findings underscore the viability of data-driven computational approaches in tailoring high-performance thermoelectric materials, opening avenues for utilizing atomic-layered topological materials in efficient energy conversion applications.

Rationales/Problem statements:

The development of highly efficient thermoelectric materials for energy conversion faces limitations using traditional methods. This study tackles this challenge by utilizing data-driven computational techniques to design and produce advanced thermoelectric materials in atomic layers, with a specific focus on SnSe/$SnSe_2$ topological structures. Current synthesis methods struggle to control layer thickness and exploit topological properties that are crucial for enhancing thermoelectric performance. To overcome these limitations, this research aims to use thin film sputtering and liquid-phase exfoliation. By employing computational models to guide the fabrication process, precise layer manipulation and effective extraction of ultra-thin layers can be achieved. By uncovering the relationship between atomic structure and thermoelectric properties, this study seeks to pioneer the development of high-performance thermoelectric materials, offering a promising pathway for efficient energy conversion technologies.

Objectives:

1. To synthesis 3D to 2D topological thermoelectric materials
2. To characterize microstructure and measured thermoelectric properties of 2D topological thermoelectric materials
3. To design and perform experiments to observe the giant Seebeck effect anomalous Nernst effect (ANE) in 2D topological thermoelectric materials
4. To join with the Japanese and Indonesian group gather the new database of 2D topological materials that are potential for thermoelectric applications

Progress/Findings/Results:

A research team has conducted a study and synthesis of thermoelectric material, $SnSe_2$, at the atomic level. The material was prepared using the liquid-phase exfoliation method. The team studied the structure and thermoelectric properties of the material and found that after synthesizing the nanolayers of $SnSe_2$ using the liquid-phase exfoliation method, they coated it with a variety of nano-sized solvent films on a silicon/silicon dioxide substrate. The coated material was then annealed at a temperature of 623 K and analyzed for its crystal structure using an X-ray diffractometer. It was found that the example that passed the phase exfoliation showed the layered nanostructure of $SnSe_2$, but impurities were still observed on the **(**100) plane. However, when the example that passed the phase exfoliation was annealed at the above-mentioned temperature, the layered structure showed an increased exfoliation of $SnSe_2$**.** This can be observed from the sharp peak and the single-layered trigonal structure that is consistent with the reference JCPDS #38-1055. Meanwhile, the study of the nanoparticle structure of the exfoliated sample after annealing showed the formation of a thick film layer with a thickness of 1 μm. The synthesis of thin films of SnSe using SnSe target (NEOVAC, Purity 4N, Size D76.2x0.25", Quantity 1 PC, Thailand) by RF Magnetron Sputtering. The X-ray diffraction patterns of SnSe thin films, annealed at different temperatures, were analyzed. The patterns exhibited peaks at angles of 25.48°, 30.62°, 31.58°, 37.56°, 40.8°, 41.68°, 47.92°, 49.66°, and 53.34° in the (201), (011), (111), (311), (102), (411), (320), (511), and (420) planes, respectively. These results were obtained from the standard reference PDF No 048-1224 (Assili, Gonzalez, Alouani, & Vilanova, 2020). It can be concluded that SnSe thin films deposited on SiO_2 substrates exhibit an orthorhombic crystal structure. The analysis result of the electrical resistance (Resistance; R) of thin film technology SnSe reveals the following comparisons when annealed at different temperatures: The annealing at 400 °C yields the lowest electrical resistance value of 54 kΩ, followed by the annealing at 350 °C with 122 kΩ, then at 300 °C with 198 kΩ, and at 450 °C with 719 kΩ. As for the annealing at 250 °C, the analysis result using scanning electron microscopy and X-ray energy dispersive spectroscopy of the SnSe thin film coated on a glass substrate indicates that the surface morphology and thickness of the SnSe thin film are consistent and well adhered to the substrate. Moreover, the analysis of elemental composition using X-ray energy dispersive spectroscopy confirms that the coated elements on the substrate consist of Sn and Se, indicating that the thin film coating on the substrate is a SnSe thin film.

Conclusion:

In conclusion, the study demonstrates the synthesis and characterization of $SnSe_2$ and SnSe thin films at the atomic level using liquid-phase exfoliation and RF magnetron sputtering techniques, respectively. Annealing significantly impacted the crystal structures, revealing enhanced exfoliation and formation of a trigonal $SnSe_2$ structure. While SnSe thin films deposited on SiO_2 substrates showcased an orthorhombic crystal structure. Electrical resistance analysis highlighted optimal annealing at 400°C for SnSe thin films. Scanning electron microscopy confirmed well-adhered coatings on glass substrates, rich in Sn and Se elements. These findings underscore the structural variations and electrical properties of synthesized thin films, offering insights into their potential for diverse applications in electronic and optoelectronic devices.

Current Output: (for example: Publication/patent/prototype)

1. Spintronic Thermoelectric Properties of Amorphous Fe-Ti-Sb Thin Films, Journal of Electronic Materials, 52(2), 989 - 993. (2023)
2. Enhancing the Thermoelectric Power Factor of Mg_2Si/MgO Composites by Ag and

Bi Codoping, Journal of Electronic Materials, 1-7. (2023)
3. Effect of substrate rotation and rapid thermal annealing on thermoelectric properties of Ag-doped Sb_2Te_3 thin films, Vacuum, 211, 111920. (2023)
4. Transparent-flexible thermoelectric module from In/Ga co-doped ZnO thin films, Chemical Engineering Journal, 465, 142954. (2023)
5. Bulk and Thin Film TE Materials and Applications, encyclopedia (2023)
6. Microstructural and thermoelectric properties of PbTe single crystals as grown by Czochralski method, Materials Letters 324 (2022) 132798
7. Spin-tunable thermoelectric performance in monolayer chromium pnictides, Physical Review Materials, 6 (2022) 064010

Challenges/Problems and Possible solutions:

Challenges/Problems:

1. Precision in Synthesis: Achieving consistent atomic layers and topological properties using thin film sputtering and liquid-phase exfoliation for $SnSe/SnSe_2$ synthesis poses challenges due to varying layer thickness and potential impurities.
2. Characterization Complexity: Accurately identifying impurities or defects within the layers post-synthesis is intricate, complicating the assessment of structural integrity.

Possible Solutions:

1. Enhanced Computational Models: Refining computational models to better predict synthesis parameters can improve control over atomic layers, utilizing advanced algorithms for precise simulations.
2. Advanced Characterization Techniques: Employing high-resolution microscopy and spectroscopic methods enhances impurity detection and structural analysis, aiding in improving synthesis quality.

Addressing these challenges through refined computational models and advanced characterization techniques can facilitate a more precise synthesis of $SnSe/SnSe_2$ materials for enhanced thermoelectric applications.

Future plan:

1. Refinement of Computational Models: Continuous advancement in predictive algorithms to optimize synthesis parameters, ensuring precise control over atomic layers and enhancing thermoelectric performance.
2. Exploration of Novel Synthesis Techniques: Investigating emerging methods beyond thin film sputtering and liquid-phase exfoliation for $SnSe/SnSe_2$ synthesis, exploring their potential in improving material properties.
3. Integration of Multiscale Modeling: Incorporating multiscale modeling techniques to bridge atomic-level simulations with macroscopic material behavior, facilitating a deeper understanding of thermoelectric properties.
4. Application Diversification: Expanding the scope of application scenarios for synthesized $SnSe/SnSe_2$ materials, exploring their utility in diverse energy conversion and harvesting technologies.

Strategic advancements in computational modeling, novel synthesis techniques, and diversified applications are key aspects of the future roadmap for enhancing thermoelectric topological materials like $SnSe/SnSe_2$.

Computational Design of High Entropy Alloys for Catalyst and Battery Applications

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Project duration: 3 years, from 1 April 2022 to 31 March 2025

Current progress: 46%

Abstract:

This cooperative research project between Philippines, Japan, Singapore, and Thailand aims to computationally design high entropy alloys (HEAs) for catalyst and battery applications. Understanding the nature of HEAs, a new class of multi-component materials, will lead to their potential industrial applications. Taking advantage of atomistic calculations and materials informatics methods, we reveal the physical properties of the designed HEAs and evaluate their innovative functionalities. Starting from binary systems, we will examine the fundamental aspects of gas-surface reactions and construct a shared database. With each team's expertise on atomistic calculations, the nature of designed HEAs and their potential applications will be predicted. There will be discussions among the members to strengthen the partnership and monitor the project's progress. Scientific workshops will be held to train young and future researchers.

Rationales/Problem statements:

Surface alloys have gained much attention from their enhanced properties compared to monometallic counterparts. In multi-component alloys, there is a tendency that atoms segregate, which is further made complicated when gas molecules are present on the surface. Recently, high entropy alloys (HEAs) of five or more components have attracted interests due to eccentric synergies between atoms and hence properties. The goal of this project is to computationally design HEAs for catalyst and battery applications by atomistic calculations and materials informatics methods. It will resolve the need for a database and thorough understanding of bimetallic surfaces with adsorbates. Conclusions from alloys with less components will serve as a guide to design HEAs. This research will combine the expertise of the members of this joint project: density functional theory from Philippines group, machine learning potentials from Japan group, cluster expansion method from Singapore group, and Monte Carlo simulations from Thailand group.

Objectives:

1. Design new alloys using transition metals that are abundant in Asia for catalyst and battery applications by employing atomistic calculations coupled with materials informatics methods.
2. Train young researchers and students in various computational materials science-based investigations.
3. Foster multilateral partnership in Asia through research collaboration.

Progress/Findings/Results:

• Developed a Monte Carlo method to calculate single- and poly-crystalline structures of an alloy consisting of 5 elements, finished the testing of such method, and calculated the structures of 3 relevant high entropy alloy systems.
• Joined kick-off meeting and spoke at seminar hosted by Philippines team on 25 April 2022.
• Underwent institutional visits and spoke at a special seminar in Singapore to strengthen collaboration with Singapore team and establish new network with three other institutes on 15-20 September 2022.
• Hosted Year-End meeting 1 in Thailand to summarize first year progress and jointly plan

research cooperation and knowledge exchange in second year on 30 March 2023.
• Organized the Symposium on Materials Modelling and Artificial Intelligence for Materials Design under the 18th NSTDA Annual Conference on 29 March 2023 in Thailand and online. Research teams from the Philippines, Japan, and Singapore also participated as speakers.

Conclusion:
From the first half of the project, we have developed a method for calculating structures of 5-element alloys with considerations of crystal structures, related reactions, and adsorbates. Thailand team has contributed to project seminars and visited research institutes in Singapore for knowledge exchange activities. Year-end meeting 1 of the joint project was hosted in Thailand. A public symposium was also organized in Thailand and online for knowledge exchange and dissemination with the Thai and international research communities as well as students.

Current Output:
• Trained 7 project co-researchers, research assistant, and student based in Thailand.
• Developed calculation method and produced results that will be used for research articles.
• Built cooperation and started working with A*STAR Institute of High Performance Computing, Singapore, University of the Philippines Los Baños, the Philippines, and the University of Tokyo, Japan.
• Hosted a knowledge exchange venue through the symposium participated by 126 people.

Challenges/Problems and Possible solutions (if any):
Uncertainties from COVID-19 and international travel may disrupt or delay planned activities. Solutions include careful planning and readiness to make adjustments so that work can proceed as efficiently as possible. There are also difficulties in recruiting skilled and experienced personnel in a very specific field. Possible solutions may be recruiting personnel with good background knowledge and promoting their developments in the desired areas.

Future plan:
We plan to develop Monte Carlo method for gas molecules-high entropy alloys and investigate elemental distribution at grain boundaries in HEAs with adsorbates. Moreover, grain boundary stability with adsorbates as well as the effects of grain size will be explored. Knowledge exchange activities with Philippines team are planned for January 2024 and exchanges with Japan team are on plan for the next year.

Functional Hybrid Polymeric Nanoparticles for Quantitative Analysis of Industrial Chemicals and Biochemicals Employing Microfluidic System

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 90 %

Abstract:

This project aims to fabricate the functional hybrid nanoparticles for quantitative analysis of industrial chemicals and/or biomolecules in the environment in the microfluidic system. The functional hybrid nanoparticles having various morphologies such as hollow, and porous have been successfully fabricated and applied in various applications. Moreover, the amine- functionalized nanoparticles were synthesized and the particles were used as nanosorbent for 2-phosphonobutane-1,2,4-tricarboxylic acid (PBTC) detection by a simple latex agglutination. The latex aggregation in the presence of PBTC was considered and generated the mapping of the aggregation domain as a function of both PBTC concentration and pH. Interestingly, the prepared nanoparticles can serve as an effective nanomaterial for detecting organophosphate with fast responding and providing quantification information.

Rationales/Problem statements:

PBTC has played an important role in circulating cooling systems and wastewater treatment, which are corrosion inhibitors to prevent scale deposits and extend the usage of industrial facilities. The reagent measurement in raw and treated water is required for qualitative and quantitative rate monitoring. Since PBTC is readily adjusted with the pre-existing water and no change in the aqueous chemistry, the dosage rate is difficult to detect and requires complex procedures to determine the presence of phosphate compounds.

Objectives:

1. To synthesize functional polymeric nanoparticles e.g., amine-functionalized polystyrene nanoparticles *via* an emulsifier-free emulsion polymerization
2. To apply the synthesized nanoparticles as nanosorbent material for PBTC detection by the colorimetric method

Progress/Findings/Results:

The adsorbent; positively charged polystyrene latex nanoparticles, was prepared *via* an emulsifier-free emulsion polymerization. The obtained amine-functionalized polystyrene particles show monodispersity with an average diameter of 100 nm. The incorporated preliminary amine originated from the comonomer produces high positive value of zeta potential (46 mV) at pH below 10. For PBTC detection, the aggregation of latex particles should be related to the incubation pH and PBTC concentration for a given latex particle amount. Specific attention is dedicated to rapid agglutination only in order to detect the PBTC concentration range in unknown aqueous samples. The results showed that the aggregation clearly observed at pH 5-7 at high concentration of > 100 ppm. The observed aggregation of latex particles is due to surface charge screening leading to low charge particles and low colloidal stability of the dispersion.

Conclusion:

The amine-functionalized nanoparticles have been successfully prepared *via* an

emulsifier-free emulsion polymerization. The synthesized nanoparticles were then applied as nanosorbent materials for specific detection of the targeted chemicals i.e., PBTC. The qualitative and quantitative detection of PBTC was successfully investigated by using a simple latex agglutination assay. By using a simple technique, however, PBTC with high concentration >100 ppm was clearly detected. The colorimetry assay (CAS assay) is developed to overcome the limitation of detection and suitable for practical use in cooling system.

Current Output:

1. K. Thananukul, C. Kaewsaneha, P. Sreearunothai, A. Petchsuk, S. Buchatip, W. Supmak, B. Nim, M. Okubo, P. Opaprakasit, Biocompatible degradable hollow nanoparticles from curable copolymers of polylactic acid for UV-shielding cosmetics, ***ACS Applied Nano Materials***, 5 (2022) 4473–4483 (Q1, IF = 5.097)
2. K. Thananukul, C. Kaewsaneha, P. Opaprakasit, N. Zine, A. Elaissari, A. Biodegradable porous micro/nanoparticles with thermoresponsive gatekeepers for effective loading and precise delivery of active compounds at the body temperature, ***Scientific Reports***, 12(1) (2022) 10906 (Q1, IF = 4.996)
3. C. Kaewsaneha, B. Roeurn, C. Apiboon, M. Opaprakasit, P. Sreearunothai, P. Opaprakasit, Preparation of water-based alkyl ketene dimer (AKD) nanoparticles and their use in superhydrophobic treatments of value-added teakwood products, ***ACS Omega***, 7(31) (2022) 27400-27409. (Q1, IF = 4.132)
4. C. Kaewsaneha, K. Thananukul, P. Opaprakasit, P. Tangboriboonrat, P. Sreearunothai, Hybrid MXene (Ti3C2Tx)/polyaniline nanosheets as additives for enhancing anticorrosion properties of Zn-epoxy coating, ***Progress in Organic Coatings***, 173 (2022) 107173. (Q1, IF = 6.206)
5. M. Shahid, T.R. Katugampalage, M. Khalid, W. Ahmed, C. Kaewsaneha*, P. Sreearunothai, P. Opaprakasit, Microwave assisted synthesis of Mn3O4 nanograins intercalated into reduced graphene oxide layers as cathode material for alternative clean power generation energy device, ***Scientific Reports***, 12 (2022) 19043. (Q1, IF = 4.996)
6. B. Khann, D. Polpanich, P. Opaprakasit, Y. Wongngam, K. Thananukul, C. Kaewsaneha*, Fabrication of sacha inchi oil-loaded microcapsules employing natural-templated lycopodium clavatum spores and their pressure-stimuli release behavior, ***ACS Omega***, (2023) 20937-20948 (Q1, IF = 4.132)

Challenges/Problems and Possible solutions:

Although the functionalized polymeric nanoparticles can serve as nanosorbent for detecting organophosphate i.e., PBTC with fast responding and providing quantification information by using a simple technique, the quantification of detection is still limited at high concentration of above 100 ppm. This concentration is quite different with in practical use of 5-20 ppm. Then, to satisfy the requirement of PBTC detection at low concentration, the suitable technique is necessary developed.

Future plan:

The facile and effective techniques for rapid detection of PBTC at low concentration (5 – 20 ppm) will be developed.

Laser-based 3D Printing of Metal Matrix Composites: Bridging Material Processing, Physics-based Simulation, and Data-driven Modeling

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Project duration: 2 years, from December 2021 to November 2023
Current progress: 100 %

Abstract: This collaborative research, involving the Japan Welding Research Institute (JWRI), Center for Advanced Manufacturing and Logistics (CAMAL), Manufacturing Technology Excellence Center (MTEC), and King Mongkut's University of Technology Thonburi (KMUTT), focused on the laser powder bed fusion (L-PBF) production of TiC-reinforced Inconel 718. The study aimed to understand the physical mechanisms affecting microstructures, defects, and material properties. Employing a mix of theoretical and experimental approaches, the project sought to improve the quality of additively manufactured TiC-reinforced Inconel 718, with specific goals such as precise fabrication, high TiC volume fraction, and minimal defects. The research integrated a multiscale modeling approach using Discrete Element Method (DEM) and Finite Element Method (FEM) to predict melt pool dimensions accurately. The collaboration resulted in a comprehensive database and modeling platform, supporting the implementation of reduced-order models for swift and accurate predictions. Through joint efforts, the project facilitated knowledge exchange through seminars, benefitting academic and private sectors in Thailand. The research significantly advances additive manufacturing, providing a robust framework for TiC-reinforced Inconel 718 with broad implications for aerospace and advanced manufacturing.

Rationales/Problem statements: The research project addresses the imperative outlined in the 12th National Economic and Social Development Plan of Thailand, recognizing advanced manufacturing technologies as vital for sustainable economic growth. Currently, Thailand heavily relies on importing advanced technologies from leading nations, leading to technological and financial deficits due to the lack of domestic R&D. This dependence necessitates a shift towards local technological development through collaborative efforts between private sectors, universities, research industries, and international partners. The focus of the research is on additive manufacturing (AM), specifically 3D printing technology, which has transformed industries like automotive, aerospace, medical devices, and defense. The AM process, known for its suitability in highly customized and low-volume production, allows for the creation of lighter components while maintaining structural integrity—a critical advantage in industries like aerospace. The study also explores metal matrix composites (MMCs), a novel material with exceptional properties applicable in specialized fields. Despite the potential of AM and MMCs, their combination remains rare, possibly due to restrictions on third-party powder supplies. The research aims to bridge this gap, exploring the integration of AM and MMCs to unlock new material possibilities and advance Thailand's position in the global manufacturing landscape.

Objectives:

1. Fabricate Inconel 718-based MMC containing TiC reinforcement by L-PBF with low

defect and high TiC volume fraction based on material characterization and mechanical tests
2. Develop multiscale modeling approach based on Discrete Element Method (DEM) and numerical methods in continuum space such as Finite Element Method (FEM) to predict the melt pool dimensions and validate with experimental results
3. Construct database for ML and data driven modeling platform so that reduced order models could be implemented for faster prediction
4. Define optimal process conditions based on experiments and computational models so that defects such as lack of fusion, keyholing, and balling effect in additively made TiC-reinforced Inconel 718 could be minimized
5. Leverage experimental and numerical expertise from JWRI, CAMAL, MTEC, and KMUTT so that sustainable collaboration among parties could be achieved
6. Organize joint seminars to promote exchange of knowledge of AM technology for academic institutes and private sectors in Thailand

Progress/Findings/Results: The research project successfully achieved objectives in studying TiC-reinforced Inconel 718 through laser powder bed fusion (L-PBF). Combining theoretical and experimental approaches, the team gained insights into microstructures, defects, and material properties. They achieved high-quality Metal Matrix Composites (MMCs) fabrication, validated through extensive testing. A multiscale modeling approach, incorporating Discrete Element Method (DEM) and Finite Element Method (FEM), accurately predicted melt pool dimensions. A data-driven modeling platform for machine learning applications was established, reducing defects in the additively manufactured TiC-reinforced Inconel 718. The collaborative effort with JWRI, CAMAL, MTEC, and KMUTT, along with seminars, facilitated knowledge exchange, contributing significantly to the project's success and advancing additive manufacturing in Thailand.

Conclusion: In addition to research work, collaborative experimental work between researchers from JWRI, KMUTT, and MTEC included participation in the 6th International Symposium on Visualization in Joining & Welding Science. Organized by JWRI, researchers from KMUTT and MTEC engaged in fruitful discussions and knowledge exchange through oral and poster presentations. The conference served as a platform for broad learning among the institutions. Following the experimental work at JWRI, Thai researchers joined the 31st Japan International Machine Tool Fair, exploring cutting-edge manufacturing technologies. A joint seminar on additive manufacturing trends occurred in May 2023, drawing over 60 participants. Subsequent visits to KMUTT and MTEC laid the groundwork for future collaborative research, culminating in a successful workshop on additive manufacturing and the future of Thai industry in July 2023.

Current Output: Five publications in Q1/Q2 journals, Four research exchanges, Two joint seminars, One continuing joint proposal, Two researchers

Challenges/Problems and Possible solutions: N/A

Future plan: The future plan for the research project involves ongoing collaboration among JWRI, KMUTT, and MTEC, expanding the scope to explore new aspects of additive manufacturing and metal matrix composites. It includes advanced modeling, international networking, industry integration, educational initiatives, knowledge dissemination, a long-term vision, and efforts to secure funding and publish findings, aiming for sustained innovation and growth in the field.

Study of the Micro-pattern Molding Process on Plastic Products and Development of High-performance Nanocomposites

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 70%

Abstract:

Micropattern fabrication on the polymer surface with different geometries was achieved using hot embossing, injection molding, and roll to roll hot embossing for superhydrophobic and self-cleaning surface applications. The high production rate of roll to roll hot embossing was discovered. Furthermore, the combination of micropattern and composites was exhibited to obtain the new properties. The HDPE was blended with cassava pulp, together with micropatterned surface was revealed. For creating new properties, cellulose nanofiber (CNFs) and lignin nanoparticles (LNPs) were produced using microfluidizer and in-house unit of anti-solvent precipitation with ultrasonication. The production protocol for conductive carbon from lignin precursors was revealed. Nanocomposites with the attained nano-fillers exhibited excellent improvement in mechanical properties, high gas-barrier and superior UV-blocking. Further advance melt-extrusion processes offer excellent filler dispersion and distribution. The properties of the obtained nanocomposites were compared with that prepared conventional twin screw extrusion (TSE).

Rationales/Problem statements:

Micropatterned surface fabrication is a crucial issue for many applications including packaging and superhydrophobic surface. Many techniques have been proposed to achieve the new functional surface, such as hot-embossing, injection molding and s roll to roll hot embossing[1-7]. However, the basic mechanism to create micropattern surface have not yet been thoroughly investigated. Biopolymer becomes a sustainable solution for environmental concern. However, mostly biopolymers have lacking properties (poor mechanical, UV-barrier and active functions). Nanocomposites can improve properties and create active functions. Adding of bio-nanofillers is a great choice to obtain bio-based product. Many researchers have reported the method to achieve the most effective form [8, 9]. Therefore, this research focuses on investigating the influences of micropattern processing, materials, and

applications. Protocol to produce bio-nanofiller and utilization nano-fillers for nanocomposites are emphasized. Not only the new functional surface was created with micropattern but also the composites can improve the mechanical properties.

Objectives:

- To study the micro-pattern molding process on plastic products via hot embossing and roll to roll hot embossing.
- To explore and develop the micropatterned nanocomposites surface to obtain the new properties.
- To produce high-performance or active nanocomposites containing in-house nanofillers.
- To explore and investigate the nanocomposites attained from advance melt-extrusion processes, high-shear rotational process (HSE) and octa-screw extruder (OSE).
- To provide technical feasibility of advance process for the production of plastic nanocomposites.

Progress/Findings/Results:

The micropatterned PP surface was successfully fabricated using hot embossing technique. The filling ratio was reached 0.99 at temperature and force of 175°C and 300 N, respectively. After heat sealing, the peel strength of micropatterned PP and film with contact area of only 10% of sealing area revealed the easy-open property owing to the micropattern geometries and chain entanglements at interfacial zone[10, 11.]

The development of micro-patterned sheets (PP, PP composite (+Ti_2O or ZnO or CuO), HDPE and HDPE/cassava pulp composite) using 3D printing mold was succeeded. The influence of materials and hot embossing and roll to roll thermal processing parameters on the selected replication micro-nano pattern sheet by using Taguchi method was also investigated.

Furthermore, the investigation focused on the development of 3D-printable polyacrylamide hydrogels with a small micropattern loaded with lignin, using the Digital Light Processing (DLP) 3D printing technique. This was done to improve mechanical properties, as well as antioxidant and antibacterial properties.

Productions of CNFs, LNPs and conductive carbon from lignin precursors were demonstrated. High performance composites with the attained nanofiller were produced, and the key properties of each nanocomposites were examined.

Nanocomposites containing CNFs were prepared via different methods, solvent casting, conventional melt-extrusion and advance melt-extrusion. In the early stage, the mechanical properties of the solvent-casted PLA/PEG/CNFs nanocomposite films were noticed. Furthermore, the dispersion and distribution of CNFs was observed in the CNFs nanocomposites prepared from advance melt-extrusion (HSP and OSE) and the improvement of mechanical, gas and water-vapor barrier properties were supposed.

Tensile properties of UV-shielded PLA/PEG/self-formed lignin, especially toughness was improved by the addition of reactive reagents either dicumyl peroxide or maleic anhydride. An advance process, OSE was carried out to investigate the formation of lignin nanoparticles in PLA matrix. An increased residence time was expected to improve the compatibility between PLA and self-formed lignin nanoparticles. Hybrid nanocomposites of PLA/PEG/self-formed lignin and nanoclay prepared via conventional twin screw extrusion and advance HSP and OSE. Good nanofiller dispersion and distribution were found on the composites prepared via the advance processes.

Conclusion:

Micropattern fabrication on neat polymer and polymer composites with different geometries on surface was successfully achieved using hot embossing, injection molding, roll to roll hot embossing for the applications of packaging and self-cleaning surface. CNFs, spherical

lignin nanoparticles and conductive carbon from lignin precursors were manufactured via in-house processes. Nanocomposites with nano-fillers exhibited improvement in mechanical properties, gas-barrier and UV-blocking. For melt-extrusion processes, HSP and OSE offer excellent filler dispersion and distribution. The obtained nanocomposites properties were compared with that prepared conventional TSE. Overall technical feasibility of HSP and OSE will be evaluated for the production of high-performance nanocomposites.

Current Output:

- **Q1 Publication (6 publications):**
  1. Enhanced Mechanical Properties and Improving Wetting Ability of Polypropylene/Cassava Pulp Composites *J. Reinf. Plast. Compos. 2022, 0 (0),* 07316844221140637.
  2. Microfabrication of Thermoplastic Polypropylene Surface Structures via Thermal Imprinting for Controlling the Adhesion of Easy Peel Package. ACS Omega, 8, 38, 35127–35139.
  3. Nanoparticles as Sustainable Biobased Nucleating Agents of Poly(L-Lactic Acid): Crystallization Behavior and Effect of Particle Sizes. *J. Mater. Sci. 2023*.
  4. Physicochemical Properties of Lignin Nanoparticles from Softwood and Their Potential Application in Sustainable Pre-Harvest Bagging as Transparent UV-Shielding Films. *Int. J. Biol. Macromol. 2023, 229, 575–588.*
  5. Introducing hydrophilic cellulose nanofiber as a bio-separator for “water-in-salt” based energy storage devices. *Electrochim. Acta 2023, 453, 142355*.
  6. Renewable Lignin-Derived Graphene-like/PVDF Nanocomposites with High Dielectric Constant and Low Loss Tangent. *J. Phys. Chem. C 2023, 127, 34, 16979–16988*.
- **Patent (2 patents) /Petty patent (3 patty patents):**
  1. “Hot embossing machine for pattern on polymer sheet” Thai Patent, application No. 2302001981
  2. “Method of producing lignin polymer compound” Thai Patent, application No 2301004137
  3. “The organic coatings made from lignin and edible wax for packaging application and preparation methods of organic coating” Thailand Petty Patent, application No. 2303001793
  4. “Spherical carbon particles from lignin precursor” Thailand Petty Patent, application No. 2203000286.
  5. “Polymer film composites containing cellulose nanofibers: compositions and method” Thailand Petty Patent, application No. 2303001793.
- **International research collaboration:** Professor Hiroshi Ito, Research Center for GREEN Materials and Advanced Processing (GMAP), Yamagata University, Japan

Challenges/Problems and Possible solutions:

Future plan:

- Part 1: Preparation of the appropriate micropattern mold for roll to roll hot embossing and study of micropatterned polymer nanocomposites.
- Part 2: Preparation of nano-fillers and fabrications of nanocomposites are in the pipeline, and the characterizations of the attained nanocomposites will be conducted.

New Generation Flow Battery for Large-Scale Renewable Energy Application

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Project duration: 3 year, from 1 November 2021 to 31 October 2024

Current progress: 85%

Abstract:

Flow battery technology offers high capacity at lower costs but faces challenges with toxic and costly vanadium flow batteries. This project focuses on developing environmentally friendly, cost-effective zinc-based flow batteries, researching advanced materials for electrodes, membranes, and electrolytes. Key advancements include high-performance oxygen catalysts and optimized oxygen electrodes, alongside improving zinc electrode cyclability and studying their surface properties.

Rationales/Problem statements:

Three critical challenges impede the advancement of zinc-based flow batteries: enhancing the cyclability of zinc electrodes to prevent degradation and extend battery life, optimizing the Oxygen Reduction Reaction (ORR) electrode for improved energy output and efficiency, and strengthening the stability of the Oxygen Evolution Reaction (OER) electrode to ensure durability and reduce maintenance costs. Addressing these issues is essential for the viability of zinc-based flow batteries in energy storage.

Objectives:

The project aims to advance zinc-based flow battery technology by developing advanced materials for oxygen catalysts and air electrodes, innovating in-situ/in-operando analysis methods for real-time monitoring, creating high-performance carbon composite terminals, and designing ion-exchange membranes. Additionally, it seeks to establish an international research network to enhance knowledge and expertise in energy storage systems, focusing on ZFBs.

Progress/Findings/Results:

The project's outcomes are categorized into four key areas: electrode modification, oxygen electrocatalysts and electrode fabrication, electrolyte and separator systems, and modeling, operation, and control systems.

1. Electrode Modification: The enhancement of carbon felts using polymer composites has shown improved cyclability and overall battery performance. The project explores the fabrication of an artificial solid electrolyte interface (ASEI) through the use of metal-organic frameworks (MOFs) and covalent organic frameworks (COFs). These ASEIs are instrumental in protecting the zinc anode from corrosion and hydrogen evolution reaction (HER), thereby boosting coulombic efficiency and minimizing side reactions.
2. Oxygen Electrocatalysts and Electrode Fabrication: This segment focuses on catalysts for both oxygen reduction reaction (ORR) and oxygen evolution reaction (OER), crucial for discharge and charge processes of zinc-air batteries (ZABs), respectively. The advanced ORR catalysts, based on MOFs, offer the advantage of flexibility and tunability, enhancing ORR activity while reducing metal usage. For OER, the project has developed catalysts directly deposited on metal mesh, eliminating the need for carbon or binders, which addresses the stability issue of OER electrodes. The resultant binder-free OER electrodes demonstrate significantly improved stability.
3. Electrolyte and Separator Systems: The project evaluates various electrolyte systems to address corrosion and HER issues in zinc electrodes. These include hybrid electrolytes combining water with ionic liquids or ethers, nonaqueous electrolytes, and gel polymer

electrolytes.
4. Modeling, Operation, and Control Systems: Effective control and management systems are crucial for optimizing battery use. The project introduces mathematical models based on a linear parameter-varying (LPV) system, which, in combination with an extended Kalman filter, can effectively estimate the state of charge (SOC). These models are vital for the development of battery management systems. Additionally, the project emphasizes optimizing ZABs at high current densities using surrogate models.
Each of these components plays a pivotal role in enhancing the efficiency and practicality of zinc-based flow batteries, contributing to advancements in energy storage technology.

Conclusion:

In conclusion, this project represents a comprehensive advancement in zinc-air battery technology, encompassing four crucial domains: electrode modification, oxygen electrocatalysts and electrode fabrication, electrolyte and separator systems, and modeling, operation, and control systems. The innovative approaches in electrode modification have significantly enhanced battery cyclability and performance. The development of efficient oxygen electrocatalysts, both for ORR and OER, has resulted in improved stability and reduced metal usage. The exploration of diverse electrolyte systems addresses key challenges like corrosion and HER. Lastly, the implementation of sophisticated modeling and control systems paves the way for more accurate management and optimization of battery performance, marking a significant step forward in energy storage technology.

Current Output:

Publication: 32 papers (26 T1 papers and 6 Q1 papers)

Patent: 1 patent regarding the design of rechargeable zinc-air flow batteries using tri-electrode tubular structure

Prototype: Tubular tri-electrode rechargeable zinc-air flow battery

Challenges/Problems and Possible solutions:

Challenges/Problems:
1. Scaling Up: Transitioning from small-scale cells to kW-scale modules may pose challenges in maintaining efficiency and performance consistency.
2. Material Stability: Ensuring the long-term stability of advanced materials under increased operational demands.
3. System Integration: Integrating the scaled-up modules into existing energy infrastructures without compromising system reliability.
Possible Solutions:
1. Rigorous Testing: Implement comprehensive testing protocols to ensure efficiency and performance at larger scales.
2. Material Research: Continued research and development to enhance the durability and stability of advanced materials.
3. Collaboration with Energy Experts: Partner with energy infrastructure experts to seamlessly integrate the technology into existing systems, focusing on compatibility and efficiency.

Future plan:

The project aims to scale from small cells to kilowatt-capacity modules, focusing on validating practicality and efficiency in real-world scenarios, and integrating into broader energy systems while ensuring reliability and high performance for large-scale energy storage.

Innovating a Hybrid Electrochemical Solar Cell for the Production of Hydrogen and Freshwater from Seawater

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Project duration: 2 years, from 1 November 2021 to 31 October 2023
Extend: 0.5 year from 1 November 2023 to 30 April 2024
Current progress: 85%

Abstract:
We improved the efficiency of photoelectrocatalytic cells for removing organic matter and producing hydrogen gas from seawater. In addition, we designed a prototype electrodialysis (ED) cell for desalination, which could be integrated with the PEC cell. We have successfully developed a laboratory-scale prototype PEC cell that can remove 100% organic contaminants within 10 minutes as well as generate 24 ml of hydrogen per hour. The prototype of the ED cell that has been created demonstrates the capability to achieve a salinity, conductivity, and total dissolved solids removal rate of 99.7% during a 30-minute duration. We are actively working on an actual scale version for future use. We have submitted a patent application and a manuscript for publication in international journals. This research was carried out in collaboration with Eagle Dream Company Limited for future commercial development. Specifically, we established a network of collaboration between domestic and international research teams.

Rationales/Problem statements:
During the last 24 months, research has been carried out in accordance with the research proposal's research plan, which is to develop the preparation of WO_3 semiconductor electrodes combined with $BiVO_4$ to be efficient in the reaction for application to the removal of organic substances and the production of hydrogen gas from seawater. Meanwhile, a laboratory-scale prototype electrodialysis cell can be established to efficiently remove salinity and contaminants ions from seawater. We designed a real-size prototype cell and employed a contractor for its construction. However, due to delays, the contractor was unable to complete the work on time. Therefore, it is impossible to carry out the performance test within the first established deadline. Consequently, we have formally requested a six-month extension to fulfill the study project within the designated boundaries.

Objectives:
1. To develop semiconductor electrodes with high reaction efficiency for photoelectrocatalytic cells that remove organic materials and generate hydrogen gas from saltwater.
2. To develop an electrodialysis prototype cell for removing salinity from seawater.
3. To establish networks, facilitate cooperation, and promote the exchange of modern technology and knowledge between laboratories domestically and internationally.
4. To develop the prototype cell innovation to produce hydrogen and fresh water from seawater for commercial distribution.

Progress/Findings/Results:
The efficiency of photoelectrocatalytic (PEC) cells was enhanced in order to

facilitate the removal of organic matter and the production of hydrogen gas from saltwater. Furthermore, a prototype electrodialysis (ED) cell was developed for desalination, with the potential for integration with the PEC cell. A laboratory-scale prototype of a PEC cell has been successfully developed, exhibiting its ability to generate 25 ml/hr. of hydrogen and completely remove organic pollutants within 10 minutes. The developed ED cell prototype exhibits the capacity to remove total dissolved solids, conductivity, and salinity at a rate of 99.7% within 30 min. The important characteristics of the electrodes that were developed and the reaction mechanisms of each electrochemical cell were successfully evaluated. At present, the PEC cell system is utilized in conjunction with a production-scale ED cell system for the purpose of producing fresh water and hydrogen gas from seawater. The performance of the designed system will be further evaluated, and an assessment of the viability of commercial manufacturing will be conducted. We are capable of preparing and submitting three research manuscripts for publication in Q1-level international research journals and of applying for three invention patents. On a laboratory scale, we have successfully developed a prototype electrochemical cell capable of extracting hydrogen gas and organic substances, as well as measuring salinity, from seawater. Presently, we are in the process of fabricating a practical-scale prototype electrochemical cell that incorporates an electrical control system and can produce both hydrogen and freshwater from seawater. The present study was conducted in partnership with Eagle Dream Company Limited with the aim of facilitating future business developments. Our efforts focused on establishing a collaborative network among research teams both domestically and internationally.

Conclusion:

The investigation was conducted in accordance with the research proposal's research plan, which aimed to improve the reaction efficiency of WO_3 semiconductor electrodes combined with $BiVO_4$ for use in the production of hydrogen gas and the removal of organic substances. It is achievable to develop a laboratory-scale electrodialysis cell prototype that effectively eliminates salinity and contaminant ions from seawater. A practical scale prototype cell has been built and implemented, and performance testing will be completed as planned.

Current Output:

- A laboratory scale photoelectrocatalytic cell prototype for organic removal and H_2 production, as well as an electrodialysis cell for fresh water production from seawater.
- Patent applications have been submitted for three innovations derived from research findings.
- We have submitted the three manuscripts for publishing research at the international level in the Scopus database, specifically targeting the Q1 quality level.

Challenges/Problems and Possible solutions:

Because of delays in delivering large-scale prototype cells for practical usage, this makes dependent on time research unfeasible. As a result, we extended the study project for another **6** months, with the expectation that it would be successful in accordance with its objectives.

Future plan:

The objective of this study is to evaluate the operational efficiency of a large-scale prototype cell that integrates a photoelectrocatalytic cell and an electrocatalytic cell. The cell prototype will be subjected to automatic operation using a circuit system designed for the purpose of producing fresh water and generating hydrogen from seawater simultaneously.

BRAINPOWER CONGRESS 2023
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ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Zoonosis)

Development of Human Primary Cell Platforms to Model Pathophysiology, Pathogenesis and Therapeutic Strategies Using SARS-CoV-2 as a Model

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Project duration: 3 years, from 01 February 2021 to 31 January 2024
Current progress: 90%

Abstract: This project develops human primary cell platforms to model the pathophysiology and pathogenesis of SARS-CoV-2, focusing on different cell types and organoids. Key developments include 3D lung micro-organoids and 2.5D alveolar epithelium models, demonstrating susceptibility to SARS-CoV-2 and enabling the study of viral pathogenesis in lung tissues. A significant breakthrough is the iPSCs-derived brain cell model, highlighting SARS-CoV-2's impact on the central nervous system without triggering widespread inflammation. The project also revealed differential susceptibility to SARS-CoV-2 in Mesenchymal Stem Cells (MSCs), with adipose-derived MSCs (AD-MSCs) showing higher susceptibility than bone marrow-derived MSCs (BM-MSCs). Furthermore, human induced pluripotent stem cell-derived cardiomyocytes (iPS-CMs) were utilized for in vitro cardiotoxicity and antiviral assessment, providing insights into heart cell responses to SARS-CoV-2. The establishment of a virus-host translational network integrates these findings, enhancing understanding of SARS-CoV-2 interactions across various human cell types. Future efforts focus on optimizing single-cell analysis and exploring molecular mechanisms in these models.

Rationales/Problem statements:

The COVID-19 pandemic underscored the need for advanced in vitro models to understand SARS-CoV-2's diverse impacts on human cells. Existing models lack comprehensive representation of the virus's interaction with various cell types, hindering the development of effective therapeutic strategies and understanding of the virus's pathophysiology and pathogenesis

Objectives:

The project aims to develop and characterize human primary cell models, including lung micro-organoids, MSCs, neural iPSCs, and cardiomyocytes, to study SARS-CoV-2 pathogenesis. It seeks to understand cellular responses to infection, explore therapeutic targets, and establish an integrated virus-host translational network for comprehensive antiviral strategy development.

Progress/Findings/Results:

The project successfully developed 3D lung micro-organoids and 2.5D alveolar epithelium models, revealing their susceptibility to SARS-CoV-2 and enabling detailed study of lung cell pathogenesis. In iPSCs-derived brain cells, specific cell types exhibited viral infection, demonstrating the virus's capability to affect the central nervous system. MSCs showed differential responses to SARS-CoV-2, with AD-MSCs being more susceptible than BM-MSCs. Human iPSC-derived cardiomyocytes were effectively used for cardiotoxicity and antiviral assessments, contributing vital insights into cardiac responses to the virus. These

findings collectively enhance understanding of SARS-CoV-2 interactions across varied cell types and organ systems.

Conclusion: This project marks a significant advancement in modeling SARS-CoV-2 interactions with various human cell types. The development of lung micro-organoids, neural iPSCs, MSCs, and cardiomyocyte models provides a versatile platform for studying viral pathogenesis and cellular responses. The findings reveal the virus's differential impact on diverse cell types, enhancing our understanding of its systemic effects. These models prove crucial for screening potential therapeutic agents, offering a comprehensive approach to tackling COVID-19. Establishing a virus-host translational network paves the way for integrated research, contributing significantly to the global effort in combating current and future viral pandemics.

Current Output:

4 Protocols of tissue modeling

2 Manuscripts in preparation

2 Manuscripts under review:

1. Neuropilin-1 is a Key Determinant of Susceptibility to SARS-CoV-2 Omicron Infection in Human Adipose Tissue-Derived Mesenchymal Stem Cells

2. Unveiling the Antiviral Properties of Panduratin A Through SARS-CoV-2 Infection Modeling in Cardiomyocytes

Challenges/Problems and Possible solutions:

Addressing tissue variability and adapting models for other viruses are key challenges. Solutions include standardizing protocols across diverse donor tissues to reduce variation and customizing cell models for different viruses. This dual approach ensures reliable results for SARS-CoV-2 and extends the models' applicability to other viral studies

Future plan:

The focus will be on refining cell models for greater physiological accuracy and adapting them to study a wider range of viruses, enhancing their relevance in virological research.

Pseudotype-based Characterization of Viruses with High Zoonotic Potential

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Project duration: 3 years, from 01 February 2021 to 31 January 2023

Current progress: 90%

Abstract:

Basic virological knowledge and tools developed for related viruses have proven critical for COVID-19 pandemic management. Similar preparation for prototype pathogens reflecting the diversity of potentially significant zoonotic viruses is critical for future pandemic preparedness. In particular, paramyxoviruses, coronaviruses and non-influenza orthomyxo-viruses have been prominent as newly emerging viruses with notable zoonotic potential. Focusing on the glycoprotein function of such viruses will be invaluable for understanding mechanisms and range of cell entry. To this end, we have developed and refined cell-cell fusion assay and pseudotyping tools to study and characterize selected glycoproteins. For each of the three virus families, we have synthesized glycoproteins for six virus species, and have successfully characterized entry requirements such as pH and protease dependence, generated pseudotyped viruses, and identified cell entry range for many of these glycoproteins.

Rationale/Problem Statement:

The COVID-19 pandemic has demonstrated the importance of pre-existing knowledge regarding SARS-CoV and MERS-CoV in managing outbreaks of closely related viruses. Given that COVID-19 will not be the last of our pandemic worries, we must continue to expand the pool of our scientific knowledge regarding viruses with zoonotic potential and the tools with which we can study them.

Due to the importance of the viral envelope in determining viral tropism and zoonotic potential, and its role as a major target for detection, treatment and prevention of disease, preparation for the next pandemic hinges on deepening our understanding of diverse viral envelopes and their function. In particular, paramyxoviruses, coronaviruses and non-influenza orthomyxoviruses have been prominent as newly emerging viruses with notable zoonotic potential. Despite the diversity of these virus families, however, research has mostly been focused on only a few notable human and animal pathogens.

Objectives:

Paramyxovirus, coronavirus and non-influenza orthomyxovirus species were selected as our prototype pathogens based on divergence from well-studied viruses and their potential for zoonotic transmission and impact. We used glycoproteins from these viruses to develop pseudotyped viruses as tools for mitigating the risk in studying uncharacterized zoonotic viruses. Using viral vectors based on lentivirus (LV), vesicular stomatitis virus (VSV), and influenza A virus (IAV), we have focused on developing tools for characterizing the glycoprotein function of viruses from the three aforementioned families as well as studying their cellular tropism and entry requirements.

Progress/Findings/Results:
We have selected and synthesized envelope glycoproteins from six paramyxoviruses (*Respirovirus, Jeilongvirus, Henipavirus, Pararubulavirus*), six non-influenza orthomyxoviruses (*Thogotovirus, Quaranjavirus),* and six coronaviruses (*Betacoronavirus, Deltacoronavirus*). A robust cell-cell fusion assay has been developed to facilitate assessment of viral glycoprotein function and entry requirements, and LV-, VSV- and IAV-based pseudotyping protocols have been refined to support pseudotyping with glycoproteins from the three virus families of interest.
Among orthomyxoviruses, the tick-borne, zoonotic thogotoviruses have proven highly amenable to pseudotyping and demonstrate broad, pH-dependent entry into cell lines from a variety of mammalian species and tissues. The coronaviruses selected for this project exhibit shared reliance on exogenous proteases to facilitate entry into a limited selection of target cells, and were best pseudotyped using the LV system. Paramyxoviruses are highly challenging, as selected viruses are highly divergent and understudied. We have successfully generated paramyxovirus pseudotypes with the LV vector and the replicating recombinant VSV vector as well as identified permissive cell lines for some of selected viruses. Given the relative lack of research into exotic paramyxoviruses, these data will provide new and important insights into this family of zoonotic viruses.
Conclusion:
We have developed tools for the characterization of viral envelopes, which determine species and cell tropism and infectivity, as well as characterized envelope function for divergent zoonotic viruses of three major viral families associated with high-risk zoonotic outbreaks. Knowledge from these selected prototype pathogens will facilitate the study and propagation of novel, phylogenetically related viruses, shortening the time required to develop diagnostic, therapeutic and prophylatic tools necessary to safeguard global public health.
Current Output:
Thamamongood *et al.* Pseudotyped zoonotic thogotoviruses exhibit broad entry range in mammalian cells. Virology 2023; 589: 109914.
Challenges/Problems and Possible Solutions:
Many newly identified animal-borne paramyxoviruses form novel genera that are characterized by unique viral glycoproteins. Generation of pseudotyped viruses using these glycoproteins has been difficult, stymied by the lack of information from related viruses that could provide clues regarding suitable host cells and compatible vector systems. Replication-competent VSV vectors have proven promising, and we are gradually expanding the boundaries of our knowledge regarding these divergent viruses.
Future Plans:
The WHO and US NIAID espouse the prototype pathogen approach for pandemic preparedness, where research into ten virus families is prioritized to generate prototype vaccines and tools that broadly apply to taxonomic groups with important ramifications for human health. To this end, we intend to continue studying paramyxoviruses, which have great zoonotic potential as well as diverse but poorly characterized glycoproteins. Additionally, while studying various thogotoviruses for this project, we noticed a notable dearth of information on tick-borne viruses and diseases in Thailand. Therefore, we will also begin to pursue the detection, identification and study of such tick-borne viruses.

Establishment of Primary Nasal Epithelium for Studying SARS-CoV2 and Potential Zoonotic Viruses

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Project duration: 3 years, from 1 June 2021 to 31 May 2024

Current progress: 70%

Abstract:

Human nasal epithelium cells (hNEC) represent the initial encounter point for respiratory viruses, influencing their entry into both the upper and lower respiratory tracts, ultimately determining disease outcome. Particularly crucial in transmitting respiratory viruses from animals to humans, cells in the nasal cavity play a pivotal role in this cross-species transmission. This research project aims to cultivate primary human nasal epithelial cells from surplus tissue obtained during sinus surgery in uninfected patients. These cells, closely mirroring the human nasal cavity, will serve as a vital tool for investigating respiratory viruses, including SARS-CoV-2 and potential zoonotic threats, facilitating a deeper understanding of the virus's ability to transition from animals to humans.

Rationales/Problem statements:

Airway epithelial cells, especially in the nasal epithelium, are proposed as the initial site of viral contact in the onset of respiratory infections in a new host. In addition to acting as a physical barrier, these cells proficiently mount immune responses, expressing anti-viral factors and secreting cytokines and chemokines to recruit and activate the immune system. The critical role of the early response in shaping disease progression underscores the need for model systems to study nasal epithelial immune responses to respiratory viruses, particularly SARS-CoV2. Intensive research is ongoing to understand host protective mechanisms, viral clearance, and factors influencing severe disease versus asymptomatic infection.

Objective:

To establish a primary human nasal epithelial model for studying responses to SARS-CoV-2 and other respiratory viruses, particularly those with potential zoonotic origins.

Progress/Findings/Results:

The differentiated human nasal epithelial cells (hNEC) have emerged as a dynamic platform, demonstrating a remarkable capacity to support the replication of influenza and SARS-CoV-2 viruses. In the context of influenza virus validation, productive viral production was meticulously confirmed through viral titration assays conducted in Madin-Darby canine kidney cells (MDCK) for influenza and Vero E6/TMPRSS2 for SARS-CoV-2. This comprehensive validation not only underscores the reliability of the hNEC model but also highlights its versatility in accommodating different viral strains.

Upon infection, the hNEC exhibited a robust response, manifesting in elevated levels of

various cytokines and chemokines. This includes notable increases in IL-6, TNF-α, IFN-λ, and IP-10, indicative of a potent immune reaction post-infection. Such heightened cytokine and chemokine responses provide valuable insights into the host's intricate defense mechanisms and contribute to our understanding of the cellular dynamics involved in combatting viral infections.

Beyond its applicability to well-known respiratory viruses, the hNEC model demonstrated its utility in studying swine-origin viruses sourced from the research network. Intriguingly, findings unveiled a lower replication rate than the seasonal human influenza virus (H1N1), shedding light on the distinctive characteristics of these viral strains and their interactions with human nasal epithelial cells.

In parallel, a proteomic analysis of SARS-CoV-2-infected hNEC yielded compelling results, showcasing a robust activation of innate immune cell proteins. This discovery is a foundation for subsequent validation studies and in-depth analyses to unravel the intricate molecular alterations induced by SARS-CoV-2 infection. Exploring these altered genes holds promise for uncovering novel therapeutic host protein targets and enhancing our understanding of the host-pathogen interplay during respiratory viral infections. Overall, the differentiated hNEC model is a pivotal tool, offering a dynamic representation of the host's responses to diverse respiratory viruses.

Conclusion:

The primary human epithelial model, as demonstrated by our established primary human nasal epithelial cells (hNEC), is crucial for in-depth research on host-pathogen interactions in vitro. This model effectively studies the replication of respiratory viruses and host immune responses. Our findings showcase the capability of hNEC to support the replication of SAR-CoV2 and influenza viruses, with variations noted among variants. Furthermore, hNEC cells respond to infection by producing cytokines and chemokines. Proteomic analysis highlights the up-regulation of various proteins in the innate immune system, suggesting potential impacts on virus replication rates.

Current Output:

Manuscript in preparation

Challenges/Problems and Possible solutions:

The development of primary human nasal epithelial cells (hNEC) is a time-consuming process, marked by inherent challenges related to donor variation that can significantly impact both the yield and quality of the cells.

Future plan:

We anticipate expanding our testing to include more potential zoonotic viruses/pseudoviruses through collaborative efforts within the network. Specifically, we plan to test RSV A/B using the hNEC models. Currently, we are in the process of validating the proteomic results to confirm our findings.

Prevalence of SARS-CoV-2 Infection and Study of Viral Localization in Feline Respiratory Tract in Thailand

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Project duration: 2 year, from 1 February 2021 to 31 January 2023
Current progress: 100%

Abstract:

Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) infection in animals has been reported rendering awareness for one health concern. We describe an investigation of SARS-CoV-2 in 863 alive pets and fatal cases of naturally infected dogs in Thailand. To indicate the potential source of infection, we performed SARS-CoV-2 genomic sequencing obtained from pets and contacted humans; SARS-CoV-2 was present in 23 cases (19 cats and 4 dogs) and sequencing showed various variants of concern (VOC). We revealed evidence of viral transmission from infected humans, as the primary source, which spread to household cats and most likely circulated between cohoused cats and caretakers. Presence of the SARS-CoV-2 surface glycoprotein, obtained from individual cat caretakers, contained sequence signatures found in the sequences of infected cats, indicating a possible exposure to the virus excreted by cats. We also co-localized SARS-CoV-2 and angiotensin-converting enzyme 2 (ACE2) receptor in various organs in infected dogs' tissue. Although pet-to-human transmission of SARS-CoV-2 is considered rare, we provide suspected episodes of human infection from animals that were initially infected through contact with infected humans. We additionally expanded the knowledge of the pathology associated with natural SARS-CoV-2 infection in dogs.

Rationales/Problem statements:

SARS-CoV-2 was first identified from humans presenting with progressive pneumonia in China, in December 2019 and subsequently spread worldwide, causing the global coronavirus disease 2019 (COVID-19) pandemic. The origins of this emergent virus in humans are still questioned and the possible roles of animals as reservoirs for SARS-CoV-2 are raised. Information about a specific cellular receptor, ACE2, for SARS-CoV-2 infection has been identified in many animal species; hence, infection of this virus in other animals is possible, and have been reported in various animals including cats and dogs. Although natural infection of SARS-CoV-2 in animals has mostly resulted from the close contact between susceptible animals and infected owners/caretakers living in the same household, animal-to-animal, and animal-to-human transmission of SARS-CoV-2 has been reported in infected farmed minks in the Netherlands. Although public health risk of exposure to SARS-CoV-2-infected animals is relatively low, awareness of potentially zoonotic involvement in the SARS-CoV-2 epidemic is needed and requires intensive focus.

Objectives:

1. To explore the molecular prevalence of SARS-CoV-2 in pets in Thailand
2. To investigate the genomic characterization of SARS-CoV-2 in pets and the possibility of reverse zoonosis to humans
3. To study the SARS-CoV-2 associated pathology and viral localization in infected animals

Progress/Findings/Results:

A total of 23/863 (2.67%) samples derived from 19 cats and 4 dogs were positive for SARS-CoV-2 qRT-PCR. The most positive cases were obtained from Bangkok (n=13),

followed by Phuket (n=5), Chonburi (n=2), Pathumthani (n=2), and Samutsakorn (n=1). The positive rates were highest in the fourth wave of COVID-19 in Thailand. The clinical signs of positive animals showed mostly asymptomatic (56.52%, 13/23), mild respiratory distress including sneezing and coughing (26.09 %, 6/23), and severe pneumonia (13.04%, 3/23). Eight qRT-PCR-positive animals (34.78%) comprising 6 cats and 2 dogs had evidence of contact with SARS-CoV-2-positive humans. Whole genome characterization was obtained from 6 cats, 2 dogs, and 1 human. Phylogenetic analysis-based complete genome sequences revealed that the obtained sequences from cats and dogs were separately clustered into a group of SARS-CoV-2 sequences originating from humans. Similar to the findings of phylogenetic tree, analysis based on the PANGOLIN pipeline segregated the SARS-CoV-2 presented in this investigation into 4 distinct clades, which were considered to be Alpha B.1.1.7 (n = 4), European lineage B.1 (n = 1) and derivative B.1.1 (n = 2), Delta B.1.617. 2 (n = 1), and Omicron BA.2 (n = 2) VOCs. Additionally, we investigated two independent SARS-CoV-2 scenarios which presented zoonotic potential during the fourth and fifth waves of COVID-19 in Thailand.

Pathological findings of naturally SARS-CoV-2-infected dogs reveal severe diffuse alveolar damage, pulmonary hyalinization and fibrosis, and syncytial formation, together with minor lesions in brain and kidney. Employing reverse transcription-digital PCR, substantial viral loads of SARS-CoV-2 were detected in lung, kidney, brain, trachea, tonsil, tracheobronchial lymph node, liver, and intestine, respectively. Using double immunohistochemistry (IHC), SARS-CoV-2 localization was markedly identified in the epithelial cells of the lung, trachea, intestine and kidneys, and moderately presented in the salivary gland and gall bladder, where the co-localization with the ACE2 was also evident. Neurons in the brainstem where exhibited lymphocytic perivascular cuffing were also found to be positive for SARS-CoV-2, despite lacking ACE2 receptor expression. In addition, SARS-CoV-2 replication within the lungs of infected dogs was confirmed by transmission electron microscopy, visualizing free viral particles within the cytoplasm or the endoplasmic reticulum of syncytial cells within the lung.

Conclusion:

Even though infection from animals back to humans is considered to be relatively low and often occurs in cases of close contact, we presented evidence of spontaneous SARS-CoV-2 transmission in a cat colony and spillover back to humans. The knowledge of pathology associated with natural SARS-CoV-2 infection in dogs is also provided, a scenario that is relatively infrequent but occasionally leads to fatal outcome. These findings might suggest the potential utility of dogs as a model for studying SARS-CoV-2 infection in humans, warranting further investigation.

Current Output: 2 publications in Tier1

1. Piewbang C., Poonsin P., Lohavicharn P., Wardhani S., Dankaona W., Puenpa J., Poovorawan Y., Techangamsuwan S. 2022. SARS-CoV-2 transmission from human to pet and transmission from pet to human, Thailand. Journal of Clinical Microbiology. 60(11): e0105822. DOI: https://doi.org/10.1128/jcm.01058-22 (Impact factor 11.677)
2. Piewbang C., Poonsin P., Lohavicharn P., Punyathi P., Kesdangsakonwut S., Kasantikul T., Techangamsuwan S. 2024. Natural SARS-CoV-2 infection in dogs: Determination of viral loads, distributions, localizations, and pathology. Acta Tropica. 249: 107070. doi.org/10.1016/j.actatropica.2023.107070 (Impact factor 2.7)

Challenges/Problems and Possible solutions:

Future plan: Continuing monitoring the SARS-CoV-2 infection in pets is crucial for reverse zoonosis surveillance.

Serological Response in Companion Animals and Selection of Effective Novel Coronavirus 2019 Antigens for Serodiagnosis for Preparedness of Potential Spillover of COVID-19 to Cat and vice versa

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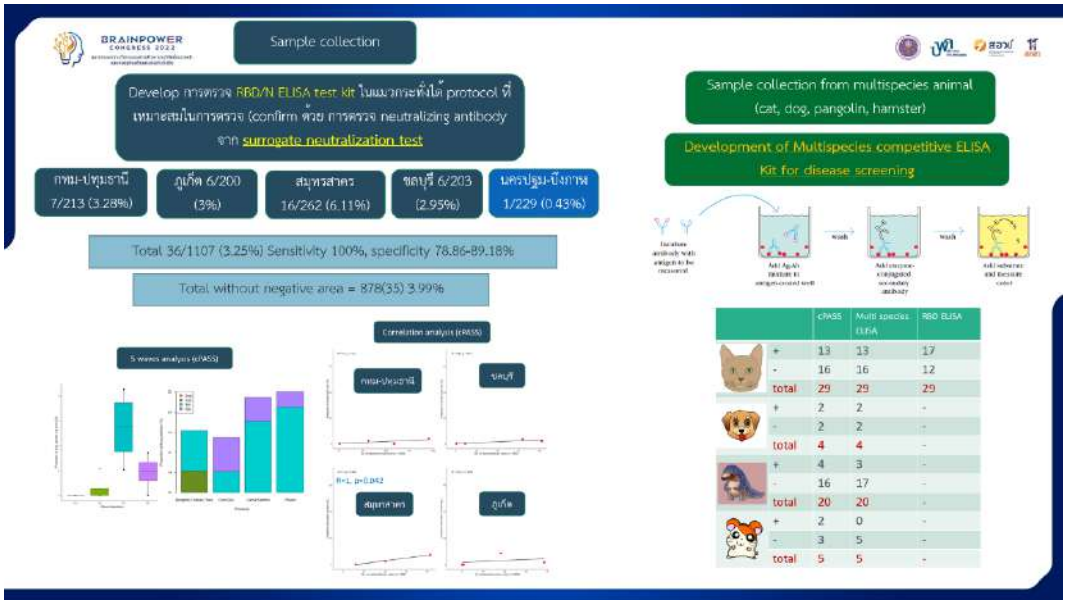
Abstract:
COVID-19 is caused by SARS-CoV-2, which is a zoonotic virus. Felines could be infected by the virus with or without respiratory symptoms. This study aims to search for suitable serological diagnosis in cats for correlation analysis compared to human cases and produces multispecies serological test kit for SARS-CoV-2 diagnosis. The results of positive cat sera for anti-RBD antibody were shown including Bangkok-Prathumthani (7/213=3.28%), Chonburi (6/203=2.95%), Phuket (6/200=3%), Samutsakorn (16/262=6.11%) and Nakornpathom-Buengkan (1/229=0.43%). The test was 100% sensitivity and 78.86%-89.18% specificity. The results show that the median number of positive cats at the 4th wave (5.54) was significantly higher than those of the 2nd (0) and the 3rd waves (0). A significant positive correlation was observed between the proportion of positive cat sera and the number of reported human cases in Samut Sakhon province (r= 1, *P*=0.042). The fitted regression model was Y = 0.1x – 1.42. In addition, the competitive ELISA and cPASS surrogate neutralization test revealed positive result of cat, dog, pangolin and hamster were 13/13(25), 2/2(4), 3/4(20) and 0/2(5) respectively. Suggesting the newly developed test could be used to detect covid-19 infection in animals.



Introduction:

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is an emerging disease virus which is closely related to severe acute respiratory syndrome coronavirus (SARS-CoV), belonging to Coronaviridae. SARS-CoV-2 is enveloped positive-sense, single-stranded RNA virus. Genome size is about 30 kb. COVID-19 is caused by zoonotic virus. Felines can be infected by the virus with or without respiratory symptoms thus it is difficult to predict disease incidence in companion animals which can spillover to human owner and vice versa.

This study aims to search for suitable serological diagnosis in cats for correlation analysis with human cases and produces multispecies serological test kit for SARS-CoV-2 diagnosis without cross reaction to feline coronavirus. Detection of the disease in animals will lead to preparedness for disease investigation, prevention, management and control.

Methodology:

In this study, we searched for suitable antigen for using in serological detection by ELISA and using human SARS-CoV-2 ELISA kit. The samples were collected from five different endemic areas (total about 1,100 samples) in Thailand, then all samples were subjected to antibody detection by human ELISA kit to S1-RBD and N proteins of SARS-CoV-2. The tests were validated for OD cutoff optimization, sensitivity and specificity of the test and chosen the candidate antigen for detection method by comparing to cPass™ Surrogate Virus Neutralization Test (sVNT). Thereafter, the percentage of infected cats would be analyzed for data correlation with human infection cases in each sample collecting area by time wave of endemic infection.

To produce multispecies serological diagnosis kit, the principle from competitive ELISA was applied. The S1-RBD protein of SAR-CoV-2 was used as an antigen, mouse monoclonal anti-RBD antibody was used as primary antibody and anti-mouse conjugated-HRP was used as secondary antibody. Positive infected sera of multi-species animals were used for test validation including cats, dogs, hamsters and pangolins. For all tests, the serum samples will be mixed with primary antibody, before putting them to antigen plate, then, the OD density of samples will be measure and compared to negative inhibition control (primary antibody alone).

Results and Discussion:

Total 1,107 cat sera were collected from animal hospitals located in Bangkok-Prathumthani, Chonburi, Phuket, Samutsakorn and Nakornpathom provinces, Thailand. Serum samples collected from Nakornpathom-Buengkan at the early of the pandemic were used as negative control. The serum samples were screened using anti-RBD ELISA test and confirmed by cPass™ Surrogate Virus Neutralization Test (sVNT). The results demonstrated that 3.26% of cat sera were positive for antibody against RBD of SARS-CoV2. The Samutsakorn showed highest seroprevalence, 6.11% (16/262), followed by Bangkok-Prathumthani (3.28%, n= 7/213), Phuket (3%, n= 6/200), Chonburi (2.95%, n= 6/203), Phuket, and Nakornpathom-Buengkan as negative infected area (0.43%, n= 1/229 = 0.43%), respectively. Interestingly, the seroprevalence of SARS-CoV2 in cats in Thailand was lower than that in Wuhan (10.7%). The test had 100% sensitivity and 78.86%-89.18% specificity when testing in endemic area, while predicting sensitivity and specificity were 96% and 89.89%, respectively.

Analysis of the relationship between infected cat with human infection cases demonstrated the data of 5 waves epidermic in Thailand. The median proportion of positive viral neutralization cat sera at 2^{nd} to 5^{th} wave were 0, 0, 5.54 and 1.98, respectively. The results show that the median number of positive cats at the 4^{th} wave was significantly higher than those of the 2^{nd} and the 3^{rd} waves. A significant positive correlation was observed between the proportion of positive cat sera and the number of reported human cases in Samut Sakhon province (r= 1, *P*=0.042). Simple linear regression was used to test if the number of reported human cases significantly predicted proportion of cPass surrogate vial neutralization positive cat sera. The fitted regression model was $Y = 0.1x - 1.42$.

The competitive ELISA and cPASS surrogate neutralization test revealed positive result of cat, dog, pangolin and hamster were 13/13(25), 2/2(4), 3/4(20) and 0/2(5) respectively.

Conclusion:

From the result, we demonstrated the anti-RBD ELISA test kit could be used as screening test for SAR-CoV-2 infection in cat after optimization the protocol compared to cPass™ Surrogate Virus Neutralization Test. The infected cat shows increasing case number

in all endemic areas along with human cases except the fifth wave of infection. The developed competitive ELISA test could be used as screening test. Although, the specificity was better than indirect ELISA (tested by using the false positive cat sera), the improvement of sensitivity was required. This serological detection protocol was developed for using in several animal hospitals in Thailand to diagnose SARS-CoV-2 infected cat led to good preparedness in disease prevention and controls of public health policy.

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The Enhancement of Innovative Behavior to Prepare Personnel in SME for Crisis Situation

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Project duration: 1.5 years, from 1 December 2021 to 31 May 2023
Current progress: 100%

Abstract:
This research aims to develop a suite of learning activities designed to foster innovative work behavior (IWB) among employees in small and medium-sized enterprises (SME) during crisis situations. It also seeks to cultivate exemplary personnel capable of implementing these learning activities. The research was grounded in educational research and development methodologies. Key findings included: 1) insights and data on IWB in the workplace, positive psychological capital, and the learning characteristics of SME personnel in crisis situations; 2) a set of e-learning based activities aimed at enhancing IWB and positive psychological capital; and 3) the preparation of prototype personnel to disseminate these activities for fostering IWB and positive psychological capital. Furthermore, the learning activities have been disseminated through the research project's website, Facebook page, and the researchers' network, inviting entrepreneurs, those involved in SME businesses, and the general public outside the research sample to access and utilize this knowledge for self-development.

Rationales/Problem statements:
Developing innovative work behaviors and positive psychological capital to prepare personnel in small and medium-sized enterprises (SME) for crisis situations is both intriguing and vital for Thailand's current scenario. This development can elevate the country's workforce, enhancing their capability to manage crises and recover post-crisis. However, most related research has focused on identifying variables associated with innovative work behavior or synthesizing innovative work behavior concepts. Research on designing and developing learning activities for fostering innovative work behavior in the working-age population, particularly in SMEs, is still limited. Therefore, it becomes compelling to explore how learning activities can be designed and developed to reinforce innovative work behaviors and positive psychological capital among SME employees.

Objectives:
1. To identify innovative work behaviors in personnel of small and medium-sized enterprises (SME) that enabled continuous business operations during the COVID-19 pandemic crisis.
2. To examine the level of innovative behavior, positive psychological capital, and learning characteristics in SME personnel.
3. To develop a set of learning activities aimed at enhancing innovative work behaviors in SME personnel.
4. To analyze the effectiveness of the learning activities in fostering innovative behavior.
5. To develop prototype personnel with innovative work behaviors capable of using the developed learning activities to enhance similar behaviors in other SME personnel.

Progress/Findings/Results:
The research's outcomes fully met its objectives, achieving 100% of the planned tasks with significant findings:

1) The development of 11 learning activities, organized into four learning modules, was successful. These included: Module 1 - "Techniques for Enhancing Positive Energy:

Confident Preparation for Life's Challenges", covering activities 1-4; Module 2 - "Learning Opportunities from Problems with Planning Techniques from Psychology", including activities 5-6; Module 3 - "Creative Idea Management Techniques for Optimal Thinking in Work", with activities 7-9; and Module 4 - "Learning to Create a Safe Space for Idea Presentation at Work", encompassing activities 10-11. The activities, developed in e-learning format and published on a website named "WorkBeat", significantly improved the participants' innovative work behavior (M=4.54, SD=0.42, statistically significant increase from M=4.09, SD=0.54, $t(31) = 4.19$, $p < .05$, $d = 0.64$) and positive psychological capital (M=4.72, SD=0.34, statistically significant increase from M=4.30, SD=0.51, $t(31) = 4.85$, $p < .05$, $d = 0.99$). Interviews reflected positive attitudes and impressions from the learning experience.

2) The project developed prototype personnel with innovative work behaviors who could use the learning activities to further develop others in SME. Participants first underwent learning in Modules 1-4 to grasp management, content, and evaluation processes before progressing to Module 5, focusing on transferring and applying knowledge more effectively in the workplace. Analysis revealed high satisfaction with all five learning modules ($M = 4.68$, $SD = 0.59$) and recognition of their applicability in work contexts ($M = 4.68$, $SD = 0.60$) and transferability to others ($M = 4.52$, $SD = 0.67$). Interviews confirmed that prototype personnel applied and refined the knowledge from these activities in their personal and professional contexts, adapting it to the learning nature and content requirements of their organizational members. Additionally, they played a mentoring role, offering information, sharing experiences, providing encouragement, and stimulating thought among their team members.

Conclusion:

The research project successfully achieved its objectives, including: 1) Acquiring knowledge and data about innovative work behaviors, positive psychological capital, and the learning characteristics of SME personnel in crisis situations. 2) Developing a set of e-learning activities to enhance innovative work behaviors and positive psychological capital. 3) Creating prototype personnel capable of disseminating these activities to develop innovative work behaviors and positive psychological capital in others. 4) Disseminating academic knowledge through presentations at international conferences and research articles in national journals.

Current Output:

The suite of e-learning activities developed for fostering innovative behavior and positive psychological capital, along with research articles published in national academic journals and presentations at international academic conferences.

Future plan:

The project plans to expand its suite of learning activities to encompass topics related to personal development, such as leadership and well-being in workplace. These additions aim to provide users with more options to address various work-related challenges. Additionally, the project has established an online social space through its Facebook page. This platform emphasizes the importance of positive psychological capital and innovative work behaviors for the working-age population. It encourages participation in relevant discussions and fosters a community or network that supports and collaborates in developing employees' capabilities to innovate and adapt to changing situations.

Artificial Intelligence Through a Contextual Game-based Learning Approach to Cultivating Digital Citizenship Behaviors

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 60%

Abstract:
This study explored enhancing digital citizenship education through an AI-driven gaming environment. It utilized a concept-effect propagation algorithm, fuzzy logic, and decision tree methods for personalization. This approach aimed to create a more engaging, contextually relevant learning experience by tailoring the game to individual decision-making patterns. Fuzzy logic interpreted student responses, and decision trees guided learning paths, while facial emotion influenced decision-making in the game. The study compared with a previous cohort using a formative assessment-based game regarding students' perceptions and motivations. It also employed eye-tracking technology to overcome the limitations of self-report questionnaires and provide a comprehensive analysis of visual attention in the gaming environment. Findings suggest that the AI-based approach, particularly through fuzzy logic and decision trees, significantly enhanced affections and altered visual attention in learning digital citizenship. It contributes to educational technology by demonstrating AI's potential to provide valuable insights for game educators and AI developers.

Rationales/Problem statements:
Digital citizenship education taught responsible and ethical technology use, covering online safety and media literacy. Prior research in this area has primarily focused on knowledge construction and cultivating digital citizenship behaviors in educational settings. However, these approaches often lack individualized feedback mechanisms, limiting their effectiveness in addressing diverse learning needs. Therefore, incorporating activities and tools that promote independent learning and engagement in digital citizenship has been crucial. This could make the learning experience more authentic and meaningful. Tapingkae et al.'s (2020) study focusing on a formative assessment-based contextual gaming approach in digital citizenship education revealed challenges associated with integrating digital games in teaching complex and dynamic concepts as digital citizenship. Accordingly, the current study is the first empirical study using an AI-driven gaming environment with a concept-effect propagation-oriented method, fuzzy logic, and decision tree to diagnose students' digital citizenship behavior status and provide personalized feedback to individuals.

Objectives:
This approach aims to diagnose students' digital citizenship behaviors and offer individualized feedback. The study explored two research questions:
(1) How did the fuzzy logic and decision tree-based personalized gaming approach impact students' affections compared to a previous cohort who received a formative assessment-based contextual gaming approach?

(2) How could eye-tracking data be analyzed to further understand the fuzzy logic and decision tree-based personalized gaming approach used for students' visual attention?

Progress/Findings/Results:

In the second year of the research project, the study proposed a gaming approach in digital citizenship education by integrating AI-powered gaming with algorithms like fuzzy logic and decision trees. The game provided personalized learning experiences through storytelling, decision-making, and graphical elements like facial emotions. The study revealed that this method significantly promoted students' perceptions and motivations compared to the traditional formative assessment-based contextual gaming approach. Eye-tracking technology was employed for in-depth analysis, showing that storytelling captivates students more, while other game aspects demand less visual focus. This method achieved a balance between cognitive engagement and attention through personalized feedback. The findings underscored the effectiveness of incorporating affection and personalization in game-based learning, highlighting the positive impact of fuzzy logic and decision trees on student engagement and perceptions in digital citizenship education.

Conclusion:

This study significantly advanced digital citizenship education by integrating an AI-driven gaming environment, where leveraging a concept-effect propagation-oriented algorithm, fuzzy logic, and decision tree methods has demonstrated a novel path for personalizing educational experiences in a digital game context. In other words, the game elements include textual representation (i.e., storytelling and decision-making) and graphical representation (i.e., facial emotion and personalized feedback).

Current Output:

- The enhanced version of fuzzy logic and decision tree-based personalized gaming approach for enhancing digital citizenship learning
- 3 proceedings indexed by SCOPUS
- 1 research article in-pressed in the International Journal of Mobile Learning and Organisation, indexed by SCOPUS (Q2) and ESCI
- 1 manuscript submitted to Computers and Education: Artificial Intelligence indexed by SCOPUS (Q1)

Challenges/Problems and Possible solutions:

There are some limitations of the current study. The study was conducted with a sample from a school; the results might not represent broader student populations, limiting the findings' applicability to diverse educational settings. The short-term study leaves questions about the sustainability of the effects of using AI-driven gaming environments on students' learning and motivation, leaving questions about the sustainability of these effects.

Future plan:

Future research could involve a more diverse and larger sample size to enhance the generalizability of the findings by conducting longitudinal studies to assess the long-term impacts of AI-driven gaming environments on learning and motivation would provide deeper insights. Researching how AI-driven gaming environments can be effectively integrated with traditional learning methods could provide a more holistic approach to education. Additionally, future studies could explore additional psychological constructs, such as social interaction, collaboration, and long-term knowledge retention.

การวางแผนและพัฒนากำลังแรงงานหลังวิกฤต COVID-19

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Project Duration: 2 ปี ตั้งแต่วันที่ 1 ธ.ค. 2564 ถึง 30 พ.ย. 2566

Current progress: 69.73**%**

Abstract: การแพร่ระบาดของ COVID-19 ส่งผลกระทบต่อ “คน” ซึ่งเป็นองค์ประกอบสำคัญในการขับเคลื่อนเศรษฐกิจ ชุดโครงการวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาและวิเคราะห์ผลกระทบต่อแรงงานไทย แรงงานต่างด้าว ภาคธุรกิจและระบบการศึกษาอย่างรอบด้านพร้อมทั้งวางแผนและพัฒนากำลังคนหลังวิกฤต COVID-19 ให้เกิดความเหมาะสมและสอดคล้องกับบริบทของเศรษฐกิจที่เปลี่ยนแปลงไป ชุดโครงการวิจัยนี้ แบ่งการศึกษาออกเป็น 3 โครงการย่อย ประกอบด้วย (1) ผลกระทบของ COVID-19 ต่อตลาดแรงงาน เศรษฐกิจและสังคม (2) ผลกระทบ ด้านภาวการณ์จ้างงานและการเข้าถึงระบบสาธารณสุขของแรงงานต่างด้าวในประเทศไทยช่วงวิกฤต COVID-19 และ (3) การพัฒนาทุนมนุษย์ของกำลังแรงงานที่ได้รับผลกระทบจาก COVID-19 ผ่านรูปแบบ STEAM Education

Rationales/Problem statements: โครงการวิจัยย่อยที่ 1 อยู่ระหว่างการวิเคราะห์เชิงลึก และการจัดประชุมระดมความคิดเห็นครั้งที่ 1 และครั้งที่ 2 เพื่อระดมความคิดเห็นยังไม่บรรลุผล เนื่องจากการวิเคราะห์ข้อมูลต้องอาศัยจำนวนและขนาดที่เพียงพอต่อกลุ่มเป้าหมายที่แตกต่างกัน คณะผู้วิจัยจึงวางแผนจัดประชุมเพื่อระดมความคิดเห็นพร้อมการจัดสัมนาเผยแพร่การศึกษาครั้งต่อไป โครงการวิจัยย่อยที่ 2 อยู่ระหว่างการวิเคราะห์เชิงลึก และการนำข้อเสนอแนะจากการระดมความคิดเห็นแบบกลุ่มจากภาครัฐ ภาคเอกชน และเครือข่ายแรงงานมาปรับปรุงผลการวิเคราะห์เพื่อจัดสัมนาเผยแพร่การศึกษาครั้งต่อไป โครงการวิจัยย่อยที่ 3 อยู่ระหว่างการวิเคราะห์เชิงลึก ทั้งนี้ ยังดำเนินการสัมภาษณ์เชิงลึก SME ไม่เสร็จสิ้น

Objectives: (1) โครงการวิจัยย่อยที่ 1 วิเคราะห์ผลกระทบ COVID-19 ต่อตลาดแรงงานในไทย การเข้าถึงโครงข่ายความคุ้มครองทางสังคมท่ามกลางการแพร่ระบาดของ COVID-19 (2) โครงการวิจัยย่อยที่ 2 วิเคราะห์ผลกระทบ COVID-19 ต่อจำนวนแรงงานต่างด้าวในไทย ผลกระทบด้านสาธารณสุขและการเข้าถึงระบบประกันสังคม และ (3) โครงการวิจัยย่อยที่ 3 วิเคราะห์ผลกระทบของ COVID-19 ต่อการปรับตัวธุรกิจของ SME เพื่อเป็นแนวทางในการเตรียมความพร้อมด้านกำลังแรงงานผ่าน STEAM Education

Progress/Findings/Results:

ในช่วง 24 เดือนที่ผ่านมา โครงการวิจัยย่อยที่ 1, 2 และ 3 สามารถดำเนินกิจกรรมได้ตามแผนงานที่ตั้งไว้ตามข้อเสนอ ผลการดำเนินงานของโครงการวิจัยย่อยที่ 1 ชี้ให้เห็นว่าผลจากการระบาดของ COVID-19 ทำให้ผู้ประกอบการลดชั่วโมงการทำงานลงและแรงงานบางส่วนถูกเลิกจ้าง เป็นที่น่าสนใจว่าแรงงานที่มีแนวโน้มที่จะได้รับผลกระทบจาก COVID-19 มากที่สุดจะตกอยู่กับแรงงานที่ไม่มีงานทำหรือถูกเลิกจ้างเพราะต้องสูญเสียทั้งงานและรายได้ โอกาสในการเข้าถึงโครงข่ายความคุ้มครองทางสังคมจึงเป็นไปได้ยากขึ้น

สำหรับผลการดำเนินงานของโครงการวิจัยย่อยที่ 2 พบว่าผลจากการติดเชื้อและแพร่กระจายของ COVID-19 ในกลุ่มแรงงานต่างด้าวส่วนหนึ่งเกิดจากความล้มเหลวของระบบบริหารจัดการแรงงานต่างด้าวของภาครัฐ การตรวจคัดกรอง COVID-19 ในรูปแบบเดิมทำได้ยากและพบว่าไม่มีประสิทธิภาพโดยเฉพาะกับแรงงานต่างด้าวที่เข้ามาแบบผิดกฎหมาย ทั้งนี้ อุปสรรคด้านภาษาทำให้แรงงานไม่สามารถเข้าถึงระบบสาธารณสุขได้ ขณะที่แรงงานผิดกฎหมายที่ไม่มีใบอนุญาตทำงานเลือกไม่ใช้บริการสาธารณสุขเนื่องจากมีโอกาสสูงที่จะโดนจับกุมและส่งกลับประเทศต้นทาง

ผลการดำเนินงานของโครงการวิจัยย่อยที่ 3 การแพร่ระบาดของเชื้อไวรัส COVID-19 ส่งผลกระทบต่อประชาชนและความมั่นคงของภาคธุรกิจ โดยเฉพาะธุรกิจ SME อย่างไรก็ตาม ผู้ประกอบการเริ่มปรับตัวให้สอดรับกับการเปลี่ยนแปลงหลังวิกฤต COVID-19 มากขึ้นทำให้เกิดความต้องการแรงงานที่มีทักษะเฉพาะมากขึ้น ทักษะวิชาชีพอย่างเดียวไม่สามารถตอบโจทย์ความต้องการแรงงานของผู้ประกอบการได้ ดังนั้น STEAM Education จะเข้ามาช่วยปิดช่องวางทางทักษะเพื่อให้เยาวชนที่กำลังก้าวเข้าสู่ตลาดแรงงานเกิดการพัฒนาทักษะและทุนมนุษย์มากยิ่งขึ้น

Conclusion: การดำเนินงานกิจกรรมในช่วง 24 เดือนส่วนใหญ่ลุล่วงตามเป้าหมายที่คณะผู้วิจัยตั้งไว้ ทั้งนี้ กิจกรรมที่โครงการวิจัยย่อยที่ 1 และ 3 ยังดำเนินงานไม่เสร็จสิ้นคือการจัดประชุมระดมความคิดเห็นจากภาครัฐ ภาคเอกชนและผู้มีส่วนเกี่ยวข้องทั้งหมด คณะผู้วิจัยจึงวางแผนการจัดประชุมหลังจากประมวลผลวิเคราะห์เรียบร้อยแล้ว การปรับแผนการดำเนินงานดังกล่าวไม่กระทบต่อแผนการดำเนินงานและผลลัพธ์ของโครงการ

Current Output: (1) โครงการวิจัยย่อยที่ 1 เอกสารเผยแพร่ประกอบการประชุมสัมมนาเชิงวิชาการระดับนานาชาติ ครั้งที่ 1 “Presented at 3rd International Conference in Business, Economic, and Finance, Can Tho University December 17, 2021” (2) โครงการวิจัยย่อยที่ 1 เอกสารเผยแพร่ประกอบการประชุมสัมมนาเชิงวิชาการระดับนานาชาติ ครั้งที่ 2 “RIN Online Workshop 2022 October 27, 2022” **และ** (3) โครงการวิจัยย่อยที่ 2 เอกสารเผยแพร่ประกอบการประชุมสัมมนาเชิงวิชาการระดับนานาชาติ “The 46th Conference of Federation of ASEAN Economist Associations (FAEA 46), Yogyakarta, Indonesia, November 17-18, 2023”

Challenges/Problems and Possible solutions: การจัดประชุมระดมความคิดเห็นจากภาครัฐ ภาคเอกชนและผู้มีส่วนเกี่ยวข้องทั้งหมดสำหรับโครงการวิจัยย่อยที่ 1 และ 3 ยังไม่บรรลุผลตามแผนที่วางไว้ คณะผู้วิจัยจึงเลื่อนการจัดประชุมระดมความคิดเห็นภายหลังจากประมวลผลวิเคราะห์เรียบร้อยแล้ว ทั้งนี้ โครงการวิจัยย่อยที่ 3 ยังดำเนินการสัมภาษณ์เชิงลึก SME ไม่เสร็จสิ้น เนื่องจากการเก็บข้อมูลมีทั้งข้อมูลแบบสอบถามและข้อมูลเชิงลึกซึ่งต้องใช้เวลาเก็บแบบสอบถามในระดับหนึ่ง

Future plan: เนื่องจากการจัดประชุมระดมความคิดเห็นสำหรับโครงการวิจัยย่อยที่ 1 และ 3 ยังไม่บรรลุผลตามเป้าหมายที่วางไว้ คณะผู้วิจัยจึงได้วางแผนการจัดประชุมระดมความคิดเห็นหลังจากประมวลผลวิเคราะห์เรียบร้อยแล้ว พร้อมทั้งได้วางแผนการจัดสัมนาเผยแพร่การศึกษาควบคู่กัน

ความท้าทายต่อไทยและอาเซียนในการสร้างความมั่นคงด้านสาธารณสุขเพื่อการพัฒนาอย่างยั่งยืนในยุคหลังโควิด-19: กรณีศึกษาเมืองชายแดนคู่แฝดไทย เมียนมา สปป. ลาว กัมพูชา และมาเลเซีย

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Project Duration: 2 ปี (20 ธันวาคม 2564 - 30 พฤศจิกายน 2566)
Current progress: 80%

Abstract:
การสร้างความเข้มแข็งด้านสาธารณสุขเมืองชายแดนคู่แฝดไทยกับประเทศเพื่อนบ้านที่ศึกษาควรดำเนินการสร้างการมีส่วนร่วมกับประเทศเพื่อนบ้านอย่างเป็นทางการและไม่เป็นทางการบนฐานทุนทางสังคม ศาสนา และวัฒนธรรม ตามแนวคิดการเรียนรู้และพหุวัฒนธรรม เพื่อร่วมกันสร้างความรู้เรา รู้เขา เข้าใจลักษณะสาธารณสุขและด้านอื่นๆ เพื่อใช้เข้าถึงการแก้ปัญหาและพัฒนาร่วมกันอย่างมีประสิทธิภาพและเท่าเทียม ส่วนประเทศไทยควรเปิดโอกาสให้ท้องถิ่นและประชาชน (ชายแดนและพื้นที่อื่นๆ) ได้มีส่วนร่วมเรียนรู้ที่จะแก้ปัญหาและพัฒนางานสาธารณสุขและด้านอื่นๆ ด้วยตนเองให้มากกว่าที่เกิดขึ้น ด้วยท้องถิ่นรู้ เข้าใจ ปัญหาและความต้องการ จึงควรเสริมสร้างความเข้มแข็งมั่นคงด้านสาธารณสุขและด้านอื่นๆ จากฐานรากให้มากกว่าการเน้นการสั่งการจากส่วนกลางและส่วนภูมิภาค ส่วนการพัฒนาความร่วมมือระหว่างประเทศควรดำเนินการผ่านสามเสาหลักของอาเซียนอย่างสมดุลเพื่อไม่ให้ส่งผลกระทบต่อเสาอื่นๆ เหมือนเช่นที่เป็นอยู่ในปัจจุบัน

Rationales/Problem statements:
ประชาคมอาเซียนและประเทศไทยดำเนินนโยบายการพัฒนาเสาความมั่นคงและเสาเศรษฐกิจจริงจังกว่าเสาสังคมและวัฒนธรรมซึ่งเกี่ยวข้องกับความมั่นคงสาธารณสุข ขณะที่ประเทศไทยซึ่งมีชายแดนติดกับประเทศเพื่อนบ้าน หากลักษณะสาธารณสุขประเทศเพื่อนบ้านไม่แข็งแรง ย่อมส่งผลกระทบต่อเสาอื่นๆ ของประเทศไทยอย่างหลีกเลี่ยงไม่ได้ ดังนั้น การพัฒนาประเทศและประชาคมอาเซียนจึงไม่ควรให้ความสำคัญกับเสาใดเสาหนึ่งเพียงอย่างเดียว ด้วยทุกเสาเกี่ยวข้องและส่งผลกระทบต่อกัน ด้วยเหตุนี้ ประชาคมอาเซียนจึงควรต้องมีระบบและกลไกที่ทำหน้าที่สร้างการมีส่วนร่วมด้านนี้และประสานการแก้ปัญหาและพัฒนาความมั่นคงด้านสาธารณสุขชายแดนให้กับประเทศสมาชิกโดยตรง จึงจะทำให้อาเซียนเป็นภูมิภาคที่มีความมั่นคง ด้านสาธารณสุข สามารถร่วมมือช่วยเหลือกันได้ทั้งในภาวะวิกฤตและภาวะปกติ จึงจะเป็นการพัฒนาที่ยั่งยืน เป็นแบบอย่างแก่ภูมิภาคอื่นๆ สืบไป

Objectives:
1. เพื่อศึกษานโยบายด้านสาธารณสุขของประชาคมอาเซียน นโยบายสาธารณสุขไทยต่ออาเซียน นโยบายด้านสาธารณสุขของประเทศเพื่อนบ้านที่ศึกษาต่ออาเซียน และนโยบายด้านสาธารณสุขในเมืองชายแดนคู่แฝดอาเซียนว่ามีลักษณะเป็นเช่นไร ทำไมจึงเป็นเช่นนั้น
2. เพื่อศึกษาความร่วมมือด้านสาธารณสุขของเมืองชายแดนคู่แฝดไทย-ประเทศเพื่อนบ้าน: เมียนมา สปป.ลาว กัมพูชา และมาเลเซียว่ามีลักษณะเป็นเช่นไร ทำไมจึงเป็นเช่นนั้น

3. เพื่อศึกษาปัญหา อุปสรรค แนวทางแก้ไขความร่วมมือด้านสาธารณสุขของเมืองชายแดนคู่แฝดในพื้นที่ศึกษา และข้อเสนอแนะเพื่อยกระดับความร่วมมือให้สามารถรับมือกับโรคระบาดอันตรายร้ายแรงใหม่ๆ ที่จะเกิดขึ้นหลังโควิด-19 ระหว่างเมืองคู่แฝดชายแดนที่ศึกษา

4. เพื่อสังเคราะห์และจัดทำข้อเสนอแนะเชิงนโยบายความมั่นคงด้านสาธารณสุขเพื่อรับมือกับโรคระบาดร้ายแรงใหม่ๆ ในอนาคตต่อรัฐบาลไทย และประชาคมอาเซียน

Progress/Findings/Results:

1) การพัฒนาความร่วมมือระหว่างประเทศสมาชิกในอาเซียนผ่านเสาความมั่นคงและเสาเศรษฐกิจต้องไม่ส่งผลกระทบต่อเสาสังคมและวัฒนธรรมที่รวมความมั่นคงด้านสาธารณสุขไว้
2) อาเซียนควรจัดระบบและกลไกในการขับเคลื่อนเสาสังคมและวัฒนธรรมเพื่อสร้างความร่วมมือ และการอยู่ร่วมกันให้มีพลังมากขึ้น
3) ประเทศไทย (กระทรวงสาธารณสุขและกระทรวงการต่างประเทศ) ควรพัฒนาการดำเนินงานจาก“การสงเคราะห์พัฒนา” เป็น “การพัฒนาอย่างมีส่วนร่วมอย่างเท่าเทียมกับประเทศเพื่อนบ้าน” ในลักษณะการพัฒนาแบบทวิภาคีและพหุภาคี เพื่อร่วมศึกษา เรียนรู้ คิด วางแผน ดำเนินการ และประเมินผลร่วมกัน จะทำให้เกิดการพัฒนาที่เป็นระบบ เท่าเทียม และยั่งยืนแก่ประเทศสมาชิกและประชาคมอาเซียน
4) ประเทศไทยควรใช้ทุนทางสังคมและวัฒนธรรมของประชาชนชายแดนที่มีร่วมกันกับประเทศเพื่อนบ้านเป็นเครื่องสร้างความสัมพันธ์ระหว่างชายแดนเพื่อเสริมสร้างความมั่นคงด้านสาธารณสุข และด้านอื่นๆ ร่วมกัน
5) ประเทศไทยควรใช้ทุนทางศาสนาในกลุ่มผู้ที่นับถือศาสนาเดียวกันและกลุ่มที่มีศาสนาต่างกัน สร้างความร่วมมือและการมีส่วนร่วมในการอยู่ร่วมกันด้านต่างๆ รวมทั้งความมั่นคงด้านสาธารณสุข ผ่านหลักการปฏิบัติที่มีร่วมกันและแตกต่างกันในศาสนานั้นๆ ให้มากขึ้น
6) ประเทศไทยควรกระจายอำนาจการเมืองการปกครองไปสู่ท้องถิ่นอย่างแท้จริงมากขึ้น เพื่อท้องถิ่นและประชาชนได้ร่วมกันเรียนรู้ คิด วางแผน แก้ปัญหา และพัฒนางานสาธารณสุข และด้านอื่นๆ ด้วยตนเอง เป็นการส่งเสริมชุมชนท้องถิ่นในการสร้างความเข้มแข็งให้กับชุมชนด้วยตนเอง
7) กระทรวงศึกษาธิการควรพิจารณาปรับปรุงเนื้อหาวิชาสาธารณสุข สุขภาพ และโรคภัยต่างๆ ในหลักสูตรระดับต่างๆ ให้สอดคล้องกับพลวัตรและพัฒนาการด้านการแพทย์สาธารณสุข และการเปลี่ยนแปลง ทั้งภาคทฤษฎีและภาคปฏิบัติในชีวิตประจำวันเพื่อเรียนรู้และปฏิบัติได้อย่างถูกต้องเท่าทันมากขึ้น
8) ประเทศไทยควรส่งเสริมคนไทยได้การเรียนรู้ภาษาประเทศเพื่อนบ้าน โดยเฉพาะอย่างยิ่งเจ้าหน้าที่ที่ปฏิบัติงานตามชายแดนควรเรียนรู้ภาษาของประเทศเพื่อนบ้าน โดยอาจเพิ่มเบี้ยภาษาเพื่อเป็นแรงจูงใจ เพื่อให้ปฏิบัติงานได้อย่างมีประสิทธิภาพ ลดอุปสรรคในการสื่อสารระหว่างกัน จะนำไปสู่การสร้างสัมพันธ์ระหว่างประเทศทั้งเป็นทางการและไม่เป็นทางการได้อย่างมีประสิทธิภาพมากขึ้น
9) อาเซียนควรจัดทำเว็ปไซต์เพื่อเป็นแหล่งเรียนรู้ภาษาประจำชาติของประเทศสมาชิกอาเซียนอย่างเป็นระบบและเข้าถึงได้ฟรี

Conclusion:

โครงการวิจัยนี้ สะท้อนภาพการพัฒนาด้านต่างๆ ของไทยและอาเซียนว่า ทั้งสามเสาหลักของอาเซียนต้องดำเนินการไปอย่างเท่าเทียม ถูกต้องตามกฎหมาย และหลักศีลธรรมของสังคม ที่คำนึงถึงผลประโยชน์ของประเทศเป็นหลัก และต้องเกื้อกูลกับเสาอื่นๆ เพื่อให้การสร้างความร่วมมือระหว่างกันในทั้งสามเสาหลักเกิดความสมดุลและยั่งยืน

Current Output:

นำเสนองานในการประชุมนานาชาติ และตีพิมพ์บทความซึ่งเป็นส่วนหนึ่งของงานวิจัยในระดับนานาชาติ 2 เรื่อง

Challenges/Problems and Possible solutions: N/A

Future plan:

1) สังเคราะห์ผลการวิจัยเพื่อจัดทำข้อเสนอแนะ และจัดทำรายงานวิจัยฉบับสมบูรณ์ส่งแหล่งทุน

2) จัดทำชุดความรู้จากโครงการวิจัยออกมาเผยแพร่ในรูปหนังสือต่อไป

3) จะนำประเด็นที่ยังเป็นปัญหาซึ่งพบจากงานวิจัยไปสู่การพัฒนาโครงการวิจัยเพื่อแก้ไขปัญหาต่อไป

โครงการวิจัยและพัฒนายกระดับการสร้างภาพยนตร์ไทยสู่ตลาดโลกและพัฒนากำลังคนที่เชี่ยวชาญระดับสากล โดยใช้ประวัติศาสตร์และวัฒนธรรมล้านนา

A Research and Development Project Utilizing Lanna History and Culture for Enhancing Thai Film Production and Developing an Internationally Skilled Workforce

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คณะการสื่อสารมวลชน มหาวิทยาลัยเชียงใหม่

Project Duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 45%

Abstract:

การผลิตภาพยนตร์ในพื้นที่และวัฒนธรรมล้านนานี้ จะเป็นการพัฒนาศักยภาพของบุคลากร ในการผลิตภาพยนตร์ที่ผสมผสานวัฒนธรรมอย่างกลมกลืน และเป็นการสร้างมูลค่าเพิ่มให้กับธุรกิจกองถ่ายในท้องถิ่น ซึ่งธุรกิจเหล่านี้มีมากมายหลายระดับ และมีศักยภาพในการผลิตงานภาพยนตร์ให้ออกสู่ระดับชาติ และนานาชาติได้ อีกทั้งล้านนายังเป็นพื้นที่ที่มีระบบห่วงโซ่อุปทานในการผลิตภาพยนตร์ครบครัน ทั้งสถานที่ถ่ายทำที่หลากหลาย การคมนาคมที่สะดวก

ผู้วิจัยคาดหวังอีกว่า เมื่อภาพยนตร์ได้รับการเผยแพร่แล้ว นอกจากจะทำให้เห็นถึงศักยภาพของห่วงโซ่อุปทานการผลิตภาพยนตร์ในเชียงใหม่ และล้านนาแล้ว ยังทำให้ธุรกิจ สินค้า และบริการในท้องถิ่น ได้รับการเผยแพร่ผ่านภาพยนตร์ในฐานะอำนาจละมุน และคาดว่าจะเกิดการขยายตัวเศรษฐกิจ สร้างความยั่งยืนให้กับท้องถิ่นได้ต่อไป

Rationales/Problem statements:

1. การประสานกับวิทยากร เพื่อให้เกิดความเข้าใจกับตัวโครงการ
2. การประสานงานกับกรรมการตัดสิน เพื่อให้เกิดความเข้าใจกับโครงการ
3. การจัดทำงบประมาณที่ไม่สอดคล้องกับการดำเนินการจริงบางประเด็น เช่นไม่มีหมวดวัสดุ ไม่มีงบประมาณที่ครอบคลุมในวันจัดกิจกรรมอบรม

Objectives:

1. เพื่อศึกษาองค์ความรู้ด้านการสร้างภาพยนตร์ของไทย เพื่อการพัฒนาภาพยนตร์คุณภาพระดับโลก
2. เพื่อศึกษาประวัติศาสตร์และวัฒนธรรมล้านนา (วัฒนธรรมร่วมระหว่างพื้นที่ 8 จังหวัดภาคเหนือ) สำหรับการสร้างภาพยนตร์
3. เพื่อสร้างกลไกการพัฒนาบุคลากรภาพยนตร์ด้านการสร้างภาพยนตร์ให้ก้าวสู่ตลาดโลก
4. เพื่อสร้างกลไกการเชื่อมโยงสู่การสร้างเทศกาลภาพยนตร์ขึ้นในประเทศไทย ไปสู่เครือข่ายระดับสากลคำถามในการวิจัย

Progress/Findings/Results:

โครงการเริ่มดำเนินการวันที่ 1 เมษายน พ.ศ.2566 โดยทีมวิจัยได้ยื่นเสนอเพื่อขอรับการรับรองจริยธรรมวิจัยในคน และสำนักงานคณะการรมการวิจัยในคน มหาวิทยาลัยเชียงใหม่ ได้ออกหนังสือรับรองการพิจารณาจริยธรรมโครงการวิจัย ในวันที่ 19 พฤษภาคม พ.ศ.2566 หนังสือเลขที่ CMUREC No. 66/081

จากนั้น ได้ประชุมกับผู้ร่วมโครงการและที่ปรึกษาโครงการ เพื่อกำหนดหัวข้อในการอบรม และสรรหาวิทยากรที่มีคุณสมบัติเหมาะสมกับหัวข้อ และดำเนินการประชาสัมพันธ์ เมื่อวันที่ 13 มิถุนายน พ.ศ.2566 ถึง 20 กรกฎาคม พ.ศ.2566 ผ่าน Facebook Page CIC CMU ซึ่งเป็นการประชาสัมพันธ์เผื่อรับสมัครผู้ผลิตภาพยนตร์เข้าร่วมโครงการ

จำนวน 10 ทีม เมื่อครบกำหนดการสมัครแล้วมีทีมเข้าร่วมสมัครจำนวน 39 ทีม คณะผู้วิจัยได้จัดประชุมเพื่อสรุปผลการคัดเลือกทีมที่จะได้เข้าร่วมโครงการจำนวน 10 ทีม โดยพิจารณาจากเรียงความ และสื่อนำเสนอแนวคิดที่ผู้สมัครส่งเข้ามาเมื่อวันที่ 26 กรกฎาคม พ.ศ.2566 และได้ประกาศรายชื่อทีมที่เข้ารอบเมื่อวันที่ 27 กรกฎาคม พ.ศ.2566

จากนั้น คณะผู้วิจัยได้จัดเตรียมอบรมความรู้ทางด้านวัฒนธรรมล้านนาและการผลิตภาพยนตร์ ในวันที่ 19 – 20 สิงหาคม พ.ศ.2566 โดยในวันที่ 19 สิงหาคม พ.ศ.2566 มีการบรรยายในหัวข้อ “ประวัติศาสตร์ล้านนา” โดย รองศาสตราจารย์สมโชติ อ๋องสกุล มีการบรรยายในหัวข้อ “ภูมิปัญญาล้านนา” โดย อาจารย์สนั่น ธรรมธิ และการบรรยายในหัวข้อ “สังคมล้านนา” โดย ศาสตราจารย์เกียรติคุณ ดร.ธเนศวร์ เจริญเมือง และในวันที่ 20 สิงหาคม พ.ศ.2566 ได้มีการบรรยายในหัวข้อ “การผลิตภาพยนตร์วัฒนธรรมร่วมสมัย” โดย คุณปรัชญา ปิ่นแก้ว และ คุณนนทรี นิมิบุตร และการบรรยายในหัวข้อ “ภาพยนตร์ไทยกับสายตานานาชาติ” โดย คุณพันธุ์ธัมม์ ทองสังข์ ซึ่งภายในวันที่อบรมได้มีการเก็บข้อมูลการวิจัยทั้งก่อนและหลังการอบรม

หลังการอบรม ทั้ง 10 ทีมได้กลับไปทำข้อเสนอโครงการการผลิตภาพยนตร์และส่งกลับมาในวันที่ 12 กันยายน พ.ศ.2566 คณะผู้วิจัยได้จัดส่งข้อเสนอโครงการวิจัยทั้งหมดให้กับคณะกรรมการตัดสินจำนวน 4 ท่าน โดยไม่ให้ทราบชื่อผู้สมัครและให้คะแนนอย่างอิสระ ในวันที่ 28 กันยายน พ.ศ.2566 คณะผู้วิจัยรวบรวมคะแนนจากคณะกรรมการทั้ง 4 ท่าน และสรุปคะแนนเพื่อให้ได้ทีมที่ผ่านเข้าสู่รอบการรับทุนผลิตภาพยนตร์จำนวน 5 ทีม ได้แก่ ทีมยอดดอย, ทีม Film Space, ทีม 1875 Studio, ทีม AXIS House และ ทีม Laokwan production ประกาศผลเมื่อวันที่ 29 กันยายน พ.ศ.2566

จากนั้นในวันที่ 5 ตุลาคม พ.ศ.2566 คณะผู้วิจัยได้ให้ทีมที่ผ่านการคัดเลือกทั้ง 5 ทีม มาลงนามในสัญญารับทุนการผลิตภาพยนตร์และมอบเงินทุนงวดที่ 1 จำนวนทีมละ 150,000 บาท เป็นที่เรียบร้อย จากนี้คณะผู้วิจัยจะได้ติดตามการดำเนินงานถ่ายทำภาพยนตร์เพื่อให้ได้ภาพยนตร์ตามสัญญาต่อไป

Conclusion:

การดำเนินงานส่วนมากเป็นไปตามแผน มีบางประเด็นที่มีการปรับเปลี่ยน ได้แก่ กิจกรรมการพิจารณาหัวข้อโดยผู้ทรงคุณวุฒิ ด้านภาพยนตร์ประวัติศาสตร์และวัฒนธรรมล้านนาโดยมุ่งเน้นบริบทล้านนา เนื่องจากคณะผู้วิจัยเห็นว่าหากต้องการให้ทิศทางของโครงการมีเอกภาพ ผู้ทรงคุณวุฒิจำเป็นจะต้องมีระยะเวลาในการเข้าใจโครงการ ดังนี้คณะผู้วิจัยจึงกำหนดหัวข้อการฝึกอบรมและวิทยากรเอง โดยคำนึงถึงความสอดคล้องกับโครงการ และในส่วนของการประกาศทีมที่ผ่านการคัดเลือก จากเดิมวันที่ 26 กันยายน พ.ศ.2566 เป็นวันที่ 29 กันยายน พ.ศ.2566 เนื่องจากต้องรวบรวมคะแนนจากทางคณะกรรมการพิจารณาข้อเสนอโครงการผลิตภาพยนตร์

Current Output:

โครงการได้ดำเนินการเก็บข้อมูลไปแล้ว 3 ส่วน ได้แก่

1. เนื้อหาจากเรียงความ หรือวีดิทัศน์ในหัวข้อภาพยนตร์มีส่วนทำให้วัฒนธรรมล้านนาเป็นวัฒนธรรมร่วมสมัยอย่างไร
2. แบบทดสอบ แบบตอบสั้น เพื่อแสดงทัศนะ โดยให้ผู้เข้าร่วมเขียน - ตอบ ก่อนการอบรม
3. แบบทดสอบ แบบตอบสั้น เพื่อแสดงทัศนะ โดยให้ผู้เข้าร่วมเขียน - ตอบ หลังการอบรม

Challenges/Problems and Possible solutions:

มีบางประเด็นที่มีการปรับเปลี่ยน ได้แก่ กิจกรรมการพิจารณาหัวข้อโดยผู้ทรงคุณวุฒิ ด้ายภาพยนตร์ประวัติศาสตร์และวัฒนธรรมล้านนาโดยมุ่งเน้นบริบทล้านนา เนื่องจากคณะผู้วิจัยเห็นว่าหากต้องการให้ทิศทางของโครงการมีเอกภาพ ผู้ทรงคุณวุฒิจำเป็นจะต้องมีระยะเวลาในการเข้าใจโครงการ ดังนี้คณะผู้วิจัยจึงกำหนดหัวข้อการฝึกอบรมและวิทยากรเอง โดยคำนึงถึงความสอดคล้องกับโครงการ

Future plan:

1. ทีมผลิตภาพยนตร์ที่ได้รับการคัดเลือกผลงานพัฒนาโครงการ (Concept paper) เป็น Story Board โดยมีผู้ทรงคุณวุฒิจำนวน 2 คน ทั้งด้านวัฒนธรรม และการผลิตภาพยนตร์ เป็นที่ปรึกษาให้คำแนะนำ
2. นำเสนอผลงาน (Story Board) และรับฟังคำแนะนำจากคณะกรรมการผู้ทรงคุณวุฒิเพื่อนำไปผลิตเป็นภาพยนตร์ (ระยะเวลาการผลิต 4 เดือน)
3. จัดเสวนาและจัดฉายภาพยนตร์จากผู้เข้าร่วมโครงการในเทศกาลภาพยนตร์ Golden North Film Festival เพื่อคัดเลือกให้รับรางวัลชนะเลิศ รางวัลรองชนะเลิศ และรางวัลชมเชยจากผลงานที่เข้าประกวด (รางวัลชนะเลิศ ได้รับเงินรางวัลเป็นจำนวน 300,000 บาท รางวัลรองชนะเลิศอันดับที่ 1 ได้รับเงินรางวัลเป็นจำนวนเงิน 150,000 บาท รางวัลรองชนะเลิศอันดับที่ 2 ได้รับเงินรางวัลเป็นจำนวนเงิน 100,000 บาท และ รางวัลชมเชย 2 รางวัล ได้รับเงินรางวัลเป็นจำนวนเงินรางวัลละ 50,000 บาท)
4. การถอดบทเรียน การผสานวัฒนธรรมล้านนาเข้ากับการการผลิตภาพยนตร์
   4.1 ผู้สร้างภาพยนตร์ที่เข้าร่วมโครงการ
      - วิเคราะห์ตัวบทจากเรียงความ หรือสื่อวีดิทัศน์ที่ส่งมาเข้าร่วม
      - Pre-test, post-test ความรู้ทางวัฒนธรรม

   4.2 ผู้ชมภาพยนตร์
      - ทำแบบสอบถามความพึงพอใจ ความเข้าใจ และสุนทรียที่เกิดจากภาพยนตร์

   4.3 ภาพยนตร์ที่ผ่านกระบวนการอบรม
      - วิเคราะห์ตัวบทของภาพยนตร์ที่ผ่านกระบวนการอบรม
5. ศึกษาแนวทางในการนำภาพยนตร์ที่ได้รับรางวัลไปฉายในเทศกาลภาพยนตร์ระดับนานาชาติเพื่อให้เกิดการเผยแพร่วัฒนธรรมล้านนาสู่สากล (Soft Power) และสร้างแรงบันดาลใจในการสร้างสรรค์ความเป็นล้านนาสู่การต่อยอดทางธุรกิจวัฒนธรรมในโครงการระยะต่อไป

Development of English Skills for Manpower in Thai Film Industry on Metaverse

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Project duration: 2 years, from 01 January 2022 to 31 December 2023
Current progress: 50-60%

Abstract:
The project, focusing on enhancing English skills in the Thai Film Industry within the Metaverse, aims to develop proficiency, create a dedicated platform, and propose guidelines for language skill development. This Action Research (AR) divides into Qualitative and Participatory, extending into Research and Development (R&D) to elevate the Thai film industry globally. Qualitative research targets students, government officials, and operational-level film personnel. Nonprobability Sampling is employed in quantitative research, utilizing techniques like Sampling and Quota Sampling. Data collection includes workshops and Focus Group Interviews, with learning assessments before and after classes. Statistical analysis involves SPSS for single-variable analysis, presenting results descriptively. This comprehensive approach seeks to advance language skills, positioning the Thai film industry on the world stage.

Rationales/Problem statements:
Human capital development aligns with the country's policies for 2020-2024. Despite growth in the film and digital media industry, a language barrier hampers Thai personnel from capitalizing on global collaborations. This research addresses the language skill gap, aiming to enhance English proficiency in the Thai film industry within virtual environments. By integrating language skills with modern technology, the project fosters an engaging learning environment, preparing students to play key roles in the industry and supporting SDG-4 for quality education. Additionally, it leverages soft power for sustainable economic growth, aligning with the Ministry of Higher Education, Science, Research, and Innovation (MHESI) policies to preserve and elevate Thailand's cultural heritage and creative economy.

Objectives:
1. Enhance English skills for personnel in the Thai film industry within a Metaverse.
2. Establish a platform for the development of English language skills within the Metaverse.
3. Propose guidelines to drive the development of English language skills for Thai film industry personnel within a Metaverse, aiming to elevate the industry globally.

Progress/Findings/Results:
Study outcomes are categorized to enhance English skills for individuals in the Thai film industry within the Metaverse. Crucial for curriculum development, the study assesses the problems and needs of stakeholders, including students, operational-level personnel, and government officials in the film industry. Utilizing workshops, Focus Group Interviews, and Content Analysis for analysis, the summarized outcomes are as follows:

1. English language skills of film industry personnel

1.1 Strengths and Weaknesses in English Language Skills of Film Industry Personnel

- Students in Film-related Subjects: The study revealed that most students exhibit strong reading skills, yet encounter weaknesses in listening, speaking, and writing. To address this, emphasis on developing listening and speaking communication skills is recommended.

- Operational-level Personnel in the Film Field: Findings indicate that operational-level film industry personnel demonstrate strengths in reading skills but face challenges in speaking, accents, and mutual understanding. Targeted interventions should address these weaknesses.
- Personnel in the Film Industry Value Chain: The study found that government officials and personnel in the film industry value chain possess strengths in reading skills but exhibit weaknesses in speaking and communication. This poses obstacles to job applications and collaboration with international film crews.

1.2 Problems and Needs in Developing English Language Skills of Film Industry Personnel

- Students in Film-related Subjects: Challenges primarily revolve around communication and listening skills, with insufficient study periods for course content. Recommendations include an emphasis on English in listening and speaking communication skills, with a focus on storyboarding and specific movie-related vocabulary.
- Operational-level Personnel in the Film Field: Challenges identified include communication barriers and accent-related misunderstandings. Collaborative problem-solving strategies are needed to overcome these issues.
- Personnel in the Film Industry Value Chain: Communication and interview skills in English emerge as significant challenges for government officials and personnel in the film industry value chain. Improvement efforts should prioritize listening and speaking skills.

1.3 English Language Development Needs of Film Industry Personnel and Benefits After Development

- Students in Film-related Subjects: Express a desire to communicate effectively using specific vocabulary, enhancing utility in film-related discussions. A priority is placed on developing advanced speaking skills.
- Operational-level Personnel in the Film Field: Aspire to communicate with the correct accent relevant to their job positions, emphasizing the development of advanced speaking skills.
- Personnel in the Film Industry Value Chain: Express a need to enhance communication skills, specifically in interviews and technical vocabulary. A high-level development of speaking skills is sought.

2. Course Overview: Developing a Platform for English Skills in a Metaverse

Encompassing 11 units, the course covers various aspects of English skill development in a Metaverse: Unit 1- Equipment; Unit 2- Role in the Workplace; Unit 3- Pre-production; Unit 4- Location; Unit 5- Casting; Unit 6- Fitting; Unit 7- Procedure for Movie Production; Unit 8- Postproduction; Unit 9- Video Editing; Unit 10- Sound Mixing; Unit 11- Preparation for the Test.

Conclusion:

Efforts to enhance teaching and learning efficiency in Thai education, aligning with global standards, necessitate a contemporary approach. This imperative extends to human resource development in the film industry. The research team, engaging academic professionals and film-related students in structured training workshops (Focus Group Interview), has pursued objectives 1-3. Utilizing an interview guide, data collection has informed the design of an English skills curriculum, featuring pre- and post-study tests and 11 learning units. Concurrently, work is progressing on a metaverse-based virtual English classroom with 11

classrooms per unit. Simultaneously, efforts are underway to create a web-based metaverse format with certificates for participants.

Current Output:

Prototype: Platform for Developing English Language Skills in 11 Metaverse Classrooms.

Events:

- Participation in the "60 Years of Creation and Development for Society" exhibition (Innovation for Society) to showcase the project.
- Inclusion in the exhibition for Science Day Week 2023 to promote the project.
- Participation in the Research and Innovation Performance exhibition to publicize the project.

Challenges/Problems and Possible solutions (if any):

- VR glasses should prioritize user-friendliness and affordability, addressing concerns for nearsighted individuals.
- Propose higher wages for English-proficient film personnel to underscore the value of effective communication.
- Prioritize specific vocabulary over academic content for enhanced accessibility and relevance.
- Develop a straightforward, beginner-friendly training system with clear instructions.
- Tailor usage to older individuals with time constraints, ensuring suitability for their learning needs.

Future plan

- A forthcoming update will enable utilization through a web browser within the Web-based metaverse, addressing usability concerns and providing accessibility anytime, anywhere. Certificates will be awarded upon completion of each lesson.
- Educational platforms are extended for agencies and personnel. Faculty members utilize them to compile learning materials for teaching movies within the Web-based Metaverse.
- Five learning centers are established to enhance English language skills within the Metaverse.

Empowering the Creative Media Industry: A Human Resource and Innovation Ecosystem Development Project

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Project duration: 1 year, from 1 April 2023 to 30 March 2024
Current progress: 50%

Abstract: This project empowers journalists and creative media professionals to engage their audience through digital tools. It involves three phases: 1) Developing a curriculum and training workshops: This equips media professionals with the tools and skills to create interactive experiences for their audiences. It fosters innovation and reinvigorates communication within each organization. 2) Experimenting with media development and technology: This supports practical skill development within organizations. It acts as a "Media Lab" where organizations can experiment with new technologies and techniques to create engaging experiences. This helps establish a model for developing participatory media. 3) Extracting lessons and creating a guide: The project analyzes the results of the training program and media development experiments. It then distills these insights into a "Journalists & Producer Guide to Digital Media Participation." This serves as a valuable resource for institutions and individuals seeking to enhance their creative media practices and leverage technology for audience engagement.

Rationales/Problem statements: Media innovation trends in recent years reveal a focus on immersive experiences, multi-platform storytelling, and VR integration for deeper audience engagement. However, media organizations struggle to convert these interactions into social impact and revenues. This project aims to bridge this gap by empowering media professionals with the skills to utilize digital tools for valuable audience participation in social issues. By fostering engagement and co-creation, we can unlock new revenue streams, build loyal communities, and create a more impactful media landscape that benefits both audiences and organizations. This project seeks to explore co-creation opportunities to develop new content and activities in collaboration with audiences, ultimately leading to increased value creation and revenue generation. Through this process, we hope to find ways to revolutionize the way we interact with media, leading to a more meaningful and sustainable media ecosystem.

Objectives:

This project has 4 objectives: 1) **Empowering Participation:** Equip journalists and creative media professionals with digital tools and skills to foster audience engagement and create a participatory media landscape. 2) **Learning from Experience:** Analyze opportunities, obstacles, and challenges in using digital technology for audience participation in Thai media. 3) **Building Capacity and Skills:** Develop a workshop curriculum and guidelines to promote the use of digital technology for participation, particularly in addressing social issues. 4) **Synergizing Innovation**: Create a prototype model for collaborative research and development of innovative creative media solutions.

Progress/Findings/Results:

This research investigates the potential of digital media tools to foster audience engagement and participation in media content. The project's findings highlight the significance of audience motivations, particularly the desire for social change and community belonging, in shaping effective participatory media strategies. Additionally, the study underscores the importance of training programs that equip individuals with the skills and knowledge necessary to leverage technology for audience interaction and content creation. The research

findings revealed several key insights:

1. Audience Motivation: a survey was administered to 476 individuals shows that a significant portion of the surveyed population (49%) expressed a strong desire to use media to create positive social change. However, a notable minority (35%) remained hesitant, highlighting the need for strategies addressing concerns and fostering participation. The desire to connect with others and build a sense of community emerged as a crucial motivator for participation, signifying the importance of fostering social interaction through media platforms.
2. Skill Development: Participants in the workshops reported significant improvements in media production skills, particularly in innovative thinking, creativity, and analytical thinking. The training program equipped participants with the ability to select appropriate media tools based on their specific goals and target audience, maximizing the potential for meaningful engagement.
3. Practical Application: Participants expressed confidence in applying their acquired skills to their actual work, suggesting a positive impact on media creation practices and audience engagement strategies in diverse contexts.

By addressing concerns, providing relevant skills, and encouraging community building, media professionals can empower individuals to become active participants in shaping the media landscape and driving positive social change.

Conclusion:

This research contributes to the growing body of knowledge surrounding participatory media and highlights the immense potential of digital tools for empowering individuals and amplifying social voices. By building upon these findings and fostering ongoing collaboration, we can create a more inclusive and impactful media ecosystem where everyone has the opportunity to participate and create impactful actions.

Current Output: (project has not finished)

Challenges/Problems and Possible solutions: -

Future plan:

Next Steps to Expanding Impact:

1) Media Lab: Collaborative Experimentation, researchers and media professionals will embark on a collaborative trial media production process from October to December 2023. These real-world experiments will offer invaluable insights into the practical implementation of participatory media strategies.
2.) Knowledge Sharing: Empowering Media Professionals: The extensive knowledge acquired during the project's training process will be leveraged to create a comprehensive online resource titled "Digital Media Production for Participation" on the Chula MOOC platform. This accessible learning experience will provide media professionals with the necessary skills and knowledge to effectively utilize digital media tools for audience engagement. Additionally, a dedicated handbook for media producers will be developed, incorporating the lecturer's content, insightful perspectives on media development, and practical tools utilized in the training program.

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนากำลังคนทักษะสูง (Industrial/Frontier Postdoc) ด้านเกษตรอาหารและการแพทย์

National Postdoctoral/ Postgraduate System of Thailand

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Project duration: 1 year, from 1 August 2022 to 31 July 2023

Current progress: 100% of planned achievements of the project plan in the reporting period. Planned success was 78%. of the plan throughout the project. Planned success accounted for 75%. of goals throughout the project.

Abstract:

The National Postdoctoral/Postgraduate Fellowship of Thailand aims to obtain criteria for selecting project proposals and supporting documents and to recruit researchers in five industrial fields: High Energy Physics and Plasma (HEP), Quantum Technology (QT), Frontier BCG S-Curves/New S-Curves Industry Industrial Branch, and Social Sciences, Humanities, and Arts (SHA). The platform aims to create a mechanism and system for developing and accumulating high-quality research personnel. This collaboration between educational institutions and target industry groups can expand results and goals, leading to more continuity, intellectual property, and advanced innovations. This will increase competitiveness at the international level, as well as investment in research developed jointly with the industrial sector. The platform supports research and development of innovations in industries that will use advanced technology in the future, promoting sustainable, systematic development. The collaboration between educational institutions and target industry groups is considered a mechanism for developing and accumulating high-quality research personnel.

Rationales/Problem statements:

Thailand is implementing a research system to increase the ratio of research and development personnel per population to 27 per 10,000 people. This system aims to create new opportunities for higher education institutions and industries, focusing on joint problem definition and international collaboration. The system also encourages the use of potential consultants and foreign researchers with postgraduate potential. The goal is to promote international innovation and industrial development networks. To develop high-level researchers, Thailand focuses on selecting high-potential researchers, planning public relations proposals, and presenting career guidelines in areas where researchers have expertise. This system aims to build a system of highly qualified researchers and accumulate highly qualified personnel on a continuous basis.

Objectives:

To develop mechanisms and accumulate highly qualified research personnel.
To support the research and innovation development of high-tech industries in the future.
To attract high-potential individuals from abroad to collaborate with higher education institutions, public research institutes, and the industry.
To attract high-potential talent within the country for careers as researchers and innovators, foster collaboration with high-potential researchers from abroad and the industry.
To create a mechanism for joint research and innovation between highly qualified research personnel domestically and internationally, in collaboration with the industry.

Progress/Findings/Results:

Discussion: Discuss, set goals, and evaluate the results that will arise from recruiting high-potential researchers, emphasizing equal participation and stakeholder involvement. Use the

Front-line Technology Research Confederation's grouping method into four sectors, involving funding providers and enablers such as foreign governments, institutions, and embassies. Actors, including Thai universities and research institutes, and users (implementers/users/demand-side) from the industrial sector and private companies, convene to discuss approaches, strategies, investments, and infrastructure development, addressing sector-specific interests. Design research questions and tools for researchers (postgraduate tool-kits).

Call for Applications: The Postdoctoral/Postgraduate Fellowship is now accepting applications from postdoctoral and postgraduate researchers. Define properties and employ tool-kits to attract high-potential applicants, categorizing researchers into four groups. Implement a Monitoring, Assessment, and Lessons Learned System to evaluate research project progress every six months, incorporating lessons learned during operation.

Results: Mechanisms and systems for developing and accumulating highly qualified research personnel have been established to support the future research and innovation of high-tech industries. Create mechanisms and systems for the development and accumulation of highly qualified research personnel between educational institutions and target industries, ensuring continuous expansion of results and goals. This effort aims to generate advanced research, intellectual property, and innovation, enhancing international competitiveness. The volume of investment in research co-developed with the industrial sector is increasing, influencing the development of research and innovation that can be further commercialized, thereby promoting domestic development. Thailand serves as a hub, attracting high-potential research and development personnel from overseas and fostering increased collaboration with the industry.

Conclusion:

The project implementation involves brainstorming, selecting criteria, and promoting proposals to recruit researchers from various industries and the private sector. The Consortium mechanism provides necessary skill development kits for researchers, and activities are organized to attract leading researchers from abroad. This project works in tandem with the development of Thailand's postdoctoral and postgraduate fellowship platform, focusing on usability and data support for researchers and postdocs. The Consortium mechanism ensures a complete and universal usability section for the platform, preparing it for future use and the development of the National Platform System of Thailand.

Current Output:

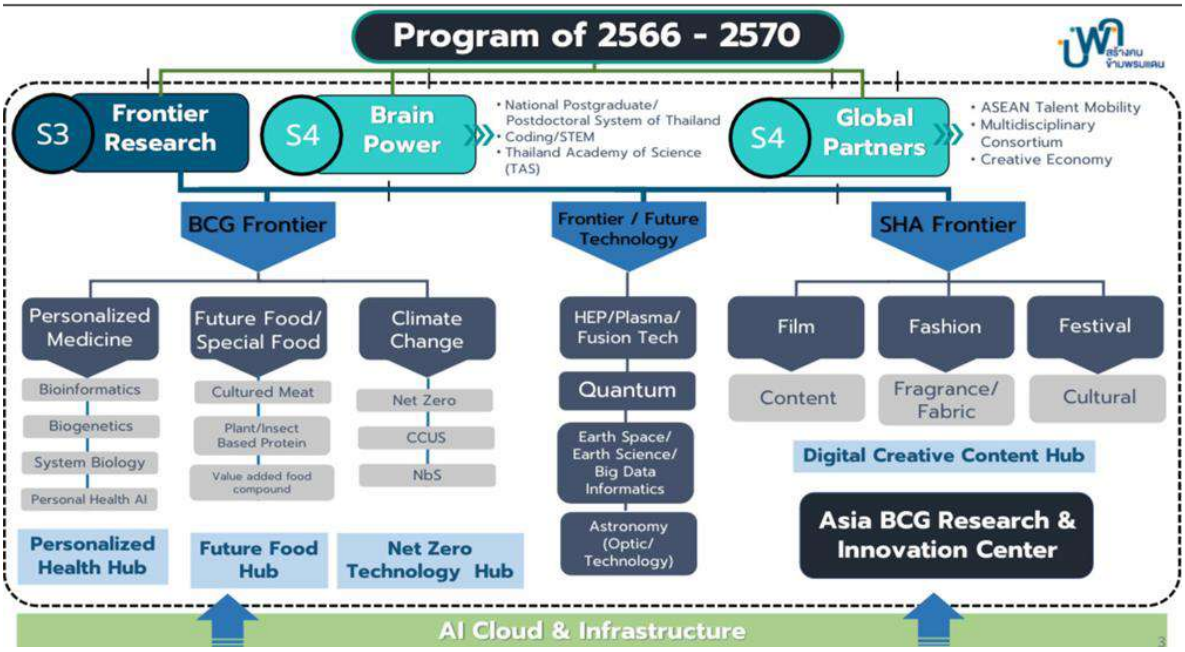
- 30 postdoctoral or postgraduate researchers with high potential in quantum, high-energy physics, earth and space science, BCG, and SHA
- Establish a system or mechanism for joint research and innovation development between foreign and domestic high-potential players together with the industrial sector.
- Undergraduate, master, or doctoral students who have been developed through system development in all 20 laboratories.
- The researcher's research is published in an international academic journal. Tier 1 or Q1 (at least 1 paper per researcher)
- The researcher's research results in product prototype form (at least 2 prototypes per New S-curve).
- The researcher's research results are in the form of patents or petty patents (at least 1 piece per New S-Curve).
- Researchers' research results in the form of technology transfer (at least 1 technology per New S-Curve)

National Postdoctoral/Postgraduate Fellowship of Thailand platform
https://postdocthailand.org/th/researcher

Challenges/Problems and Possible solutions:

The coordination of visas for foreign researchers is a significant issue, causing delays and hindering their full potential. The process is hindered by the need for quick action from various agencies. A recommended solution is to create a flowchart detailing the entire visa coordination process for foreign researchers, allowing for quicker action by embassies and related agencies. This will facilitate the process for more international researchers, ensuring a smoother experience in Thailand and facilitating their participation in the Postdoctoral/Postgraduate Researcher Program and ASEAN/ASEAN Plus Talent Mobility Program.

Future plan:



Capacity Building of Industry Focused Postmaster and Postdoctoral Researchers to Address Major Challenges in Global Food Security

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Project duration: 1 year, from 1 August 2023 to 31 July 2024
Current progress: 25%

Abstract:
The International Joint Research Center on Food Security (IJC-FOODSEC) was officially launched in July 2022 as a product of long-term and sustainable trilateral collaboration between Queen's University Belfast (UK), Thammasat University (Thailand) and National Science and Technology Development Agency (NSTDA, Thailand). It is located at BIOTEC, Thailand. IJC-FOODSEC aims to be a state-of-the-art facility for research and training for food security in the region. The IJC-FOODSEC has collaborated with a range of industries, research institutes and universities around the globe to carry out projects that cover the various spectrum of food security challenges impacting the ASEAN region. The current research project, we aim to create a system and mechanism for developing our human resources for both post-master's researchers and post-doctoral researchers in the field of food security. Currently, the consortium includes TU, BIOTEC, MTEC, Agilent Technologies, PTT OR, Thai Nam Poly Pack, PR Genetics and IVF center, and FITU. They have agreed to supervised 4 postdoctoral and 2 post-master researchers within this initiative.

Rationales/Problem statements:
Food security impacts us all; driven by overpopulation and climate change, our global food supply is under severe threat. To feed a population expected to grow to around 10 billion by 2050, the world will have to double its current food production. To make matters worse, according to the Food and Agriculture Organization (FAO), climate change has also been found to have an impact on food safety, particularly on incidences of foodborne disease and emerging contaminants. New approaches are needed to feed the current and future global population. Therefore, food security is a global challenge and as such requires worldwide collaboration from several stakeholders. Partnership from government, universities, research institutions, and industries will help create a system and mechanism for capacity building to address major challenges in global and ASEAN food security.

Objectives:
To create a system and mechanism for developing human resources either post-master's researchers or post-doctoral researchers in the field of food security which will be ready to answer and solve the country's food security challenges.

Progress/Findings/Results:
Since August 2023, it has been 4 months that IJC-FOODSEC received industrial postdoc-postmaster funding from PMU-B, therefore, six different research projects/teams are under investigating and supervising by mentors from Thammasat University, MTEC, BIOTEC NSTDA and industries. Progress will be updated to PMU-B every 3 months.

Conclusion:
IJC-FOODSEC has received funding from PMU-B since August 2024 for capacity building of industry focused postmaster and postdoctoral researchers to address major challenges in global food security. The consortium of this project consists of Thammasat university, MTEC and BIOTEC NSTDA, FITU, Agilent technologies, PTT OR, Thai Nam Poly Pack, and PR Genetics and IVF center. Six research projects are under investigation. Moreover, 3 series of soft skill workshops will be organized by IJC-FOODSEC during the upcoming year for their postdoctoral and postmaster researchers too.

Current Output:
Since August 2023, there has no publication/ patent/ prototype yet.

Challenges/Problems and Possible solutions:
Technical instrument broke down problems especially with the research project dealing with LC-MS/MS.

Future plan:
IJC-FOODSEC plans to organize the series of soft-skill workshops such as manuscript preparing and writing for Q1 journal, how to make effective and interesting research presentation, and some networking activities with our international and famous scientists for their postdoctoral and postmaster researchers.

Strengthening of Elite Researcher Platform in Beneficial Plant-Microbe Interactions

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Project duration: 1 year, from 1 April 2023 to 31 May 2024

Current progress: 50%

Abstract:

The development of a new generation researcher system through research networks collaboration with leading universities or institutions abroad is crucial for enhancing the quality and impact of academic research. This project aims to foster and empower young Thai researchers in their research endeavors, particularly in agricultural-related studies involving the relationship between plants and microorganisms. This collaboration deepens research knowledge across multiple disciplines to elevate the potential of these new researchers.

The research team collaborates with both Thai and international experts specializing in various fields. Their collective expertise aims to explore in-depth mechanisms in the plant-microbe relationship. Moreover, direct challenges from industries, like InnovFarm Biotech Limited, seeking innovative microbial products applicable to agriculture, financially supports these researchers.

The overarching research focuses on studying beneficial microorganisms that promote plant growth. This includes exploration bacteria-plant relationships within legumes and rhizosphere-associated bacteria, exploring beneficial endophytic bacteria, and arbuscular mycorrhizal fungi.

Rationales/Problem statements:

Utilizing beneficial microbes for plant growth has been a focus in agricultural research in Thailand. Research has predominantly involved selecting specific microbial strains to enhance plant growth, such as selecting rhizobium biofertilizers, PGPR biofertilizers, or strains with properties to combat plant diseases. However, it is widely acknowledged that the effectiveness of these microbial strains can vary based on the plant and microbial types, environmental conditions during application, and the rapid changes in climatic conditions. Consequently, the trend in research regarding the interaction between beneficial plant-microbe relationships necessitates in-depth studies. Understanding the underlying mechanisms goes beyond the direct plant-microbe relationship and requires attention to environmental factors and conditions of crop cultivation, impacting plant growth and yields. Comprehending the intricate mechanisms among plants, microbes, and the environment demands cutting-edge technology in various domains, including molecular biology, omics

technology, as well as chemical and biochemical analyses. This includes the use of microbes or specific microbial groups to minimize reliance on chemical substances to the greatest extent possible.

Objectives:

1. To cultivate a new generation of highly skilled researchers in agricultural biotechnology.
2. To advance academic progress in pioneering research endeavors and elevate the research output of Thai educational institutions to garner increased international recognition.
3. To fortify academic prowess, apply scholarly principles in problem-solving for companies, and facilitate the development of agricultural biotechnology product innovations for private sector companies supporting research initiatives.

Progress/Findings/Results:

The research team has divided the research project into 6 sub-projects based on consultations among the Thai research, international research teams, and private company participating in the project:

- Sub-projects 1 to 3 focus on the molecular mechanisms of interaction between legume plants and *Bradyrhizobium* sp. SUTN9-2 and *B. elkanii* USDA61 effector proteins. It has been discovered that proteins, specifically NopM and NopP2, entering plant cells, play a significant role in mutualistic interactions. We have successfully identified potential interactions of both proteins with various types of plant proteins. Additionally, within the T3SS gene system of *Bradyrhizobium* sp. strains isolated directly from the root nodules of peanuts, three strains have shown implications for enhancing mutualistic relationships in mung bean (*Vigna radiata*) and *V. mungo*.
- Sub-project 4 investigates the mechanisms of bacterial entry into plant cells, bacterial cell morphology changes, and nitrogen fixation of *Bradyrhizobium* endophytes in rice tissues and other economically important plants. It was found that the *Bradyrhizobium* sp. SUTN9-2, aside from demonstrating endophytic properties in rice tissues as previously examined, also exhibits endophytic traits in other plant tissues such as chili and tomatoes. To assess its residency ability, the strain was introduced into chili and tomato tissues for 14 days. Subsequently, plant tissues were thinly sliced to 30-40 micrometers and examined using confocal laser scanning microscopy. The results revealed that the *Bradyrhizobium* sp. SUTN9-2 is capable of residing within chili and tomato tissues. Moreover, its residency in different plant tissues influences cell properties and survival, motivating researchers to study deeper into the mechanisms controlling cell properties for further exploration.
- Sub-project 5 the mechanism behind utilizing biofertilizers for producing edible cassava under organic farming systems. For this experiment, LED light intensity of 300 µMol/m2/s (RB300) is the most suitable light condition for stimulating the development of *Arbuscular mycorrhiza* (AM) spores of *Rhizophagus irregularis* when corn is used as the host plant for spore propagation. This method has potential for using in large-scale spore production for biofertilizer purposes.
- Sub-project 6 focuses on studying the efficacy and resistance mechanism against brown spot disease in *V. radiata* CN72. It was found that cultivating the *Bradyrhizobium* sp. DOA9 significantly reduced the lesion area caused by the *Cercospora* sp. fungus. This reduction was significantly prominent when the CN72 were cultivated with the DOA9 strain either in the short term or in the long term combined with a short-term application before the *Cercospora* sp. fungus inoculation. These results demonstrate the potential of the *Bradyrhizobium* sp. DOA9 strain in effectively suppressing the severity of *Cercospora* sp. fungus in CN72 leaves.

Conclusion:

Our novel knowledge in beneficial microbes allows the reduction in chemical fertilizer and plant protection chemical usage. This reduction can significantly minimize environmental impact while also cutting crop production costs for farmers by employing microbial products as alternatives to chemical agents. This approach may empowers farmers to be self-sufficient and utilize internal technological resources within the country. Additionally, this project has plans to collaborate with specialized researchers domestically and research institutions abroad, linking research efforts with experts in omics technology and multi-omics analysis. Furthermore, it aims to build research teams comprising doctoral students and post-doctoral researchers to facilitate the contemporary transfer of technology from both local and international sources. This initiative aims to advance research endeavors and foster pioneering researchers for future breakthroughs.

Current Output:

Challenges/Problems and Possible solutions:

Future plan:

- Subproject 1 and 2 will further investigate the interaction between T3Es NopM and NopP2 with plant proteins.
- Subproject 3 aims to discover new types of T3Es that influence interdependent interactions within *Vigna radiata* and *V. mungo* plants using whole-genome techniques.
- Subprojects 4 and 5 will analyze factors affecting plant growth promotion in molecular level.
- Subproject 6 will examine the molecular-level factors of *Bradyrhizobium* sp. DOA9 to reduce the rate of plant disease caused by *Cercospera* sp.

Developing a High-performance Workforce at Post-Doctoral and Post-Master's Degree Levels in Agriculture and Food to Integrate Indigenous and Local Chicken Resource Management with Advanced Technology for S-curve Industry Group Advancement

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Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 30%

Abstract:

Indigenous and local chicken breeds, such as Mae Hong Son, Chee Fah, and Fah Luang chickens, are crucial in rural and backyard farming worldwide due to their cost-effectiveness, adaptability, and ability to thrive in challenging environments. Originating from crossbreeding with red junglefowl, these breeds play a significant socio-cultural role in Thai communities, particularly in highland environments. Preserving their genetic diversity is vital for ensuring future food security and adapting to changing production conditions. This study explores the genetic history of Mae Hong Son chickens, identifying their evolution from crossbreeding and adaptation to diverse local environments. Habitat suitability analysis reveals their distribution across Thailand, emphasizing local environmental adaptations. Understanding these mechanisms aids in enhancing commercial chicken breeds and conserving unique breeds like Chee Fah and Fah Luang chickens. The study also emphasizes the importance of nutritional and genomic scans for identifying agronomically significant genes, supported by a food bank management protocol in specific Thai border regions.

Rationales/Problem statements:

1. Genetic potential: Thai native and local chicken breeds exhibit promising traits in heat tolerance, immunity, and growth. By uncovering these specific genes, valuable insights can be gained for future studies, facilitating the utilization of beneficial genetic materials.

2. Meat, protein component and food allergens studies: The analysis of meat and protein components in these chicken breeds will enable us to determine their suitability for different purposes, providing valuable data for informed decision-making in selecting breeds for specific uses. The knowledge on an allergen will contribute for food safety for allergy consumers.

3. Food security: Understanding and utilizing the identified genetic materials, along with insights into meat and protein components, can lead to the development of robust and resilient chicken breeds, contributing to enhanced food security.

Objectives:

1. To investigate the genetic diversity of Thai indigenous chicken using microsatellite markers and mitochondrial DNA d-loop sequence. 2. To identify candidate genes associated with heat, immunity, and growth by analyzing DNA markers, particularly SNPs 3. To assess the nutritional content, amino acid profile, and allergic components of meat and eggs in each of the three chicken breeds, considering the influence of candidate genes on these traits. 4. Transfer knowledge and empower communities raising native chickens through data sharing and utilization strategies. 5. Develop high-potential researchers through postgraduate programs and industry collaboration.

Progress/Findings/Results:

Genetics and Habitat sustainability Efficient Genotyping: A new tool empowers researchers to easily study the paternity, origin, and diversity of Thai fighting chickens. Adapting to Diverse Environments: Genetic traces reveal how Lueng Hang Khao chickens have adapted to their local environments. Boosting Productivity: Understanding the link between ADSL variations and egg production can improve breeding programs. Mapping Diversity: Genetic analysis and land suitability assessments identify ideal locations for raising Lao Pa Koi fighting cocks.

Exploring human-chicken multi-relationships: This research explores the interconnectedness of humans and three Thai indigenous chicken breeds (Mae Hong Son, Fah Luang, and Samae Dam) by studying their genetic diversity, morphological characteristics, and cultural significance. Initial findings reveal distinct genetic profiles and morphologies, along with deep cultural connections evident in traditions and local identity. Further research aims to analyze genetic-morphology links and explore the socio-economic impact of these breeds on communities.

Nutrition and Food Allergens 1. Allergens: Protein profiles differed between the two breeds, particularly in the 11-50 kDa range. Enolase activity was found in both indigenous and commercial chicken, but only in the pellet of commercial chicken. Further analysis with patient sera is needed to determine allergenicity. 2. Carnosine and antioxidant activity: KU-Betong, a Thai native chicken breed, had high levels of carnosine, especially in the thighs and drumsticks. Liver had higher antioxidant activity than chicken meat. This suggests potential for native chicken as a functional meat source. 3. Egg allergens: SM and TY chicken eggs contained all six major allergens found in commercial eggs. Further testing is needed to confirm allergenicity and identify specific epitopes.

Conclusion:

This study's objective is to harness the genetic potential of Thai chicken breeds to improve food security in rural areas. It will examine the genetic diversity, heat tolerance, immunity, growth performance, and nutritional content of three Thai chicken breeds (Lueng Hang Khao, Mae Hong Son, and Pradu Hang Dam). The study aims to identify genes associated with these traits and analyze the composition of meat and protein. The findings will guide decision-makers in selecting breeds for food security programs in the future.

Current Output:

1. Possible influence of thermal selection on patterns of *HSP70* and *HSP90* gene polymorphism in Thai indigenous and local chicken breeds and red junglefowls in manuscript submitted. 2. Exploring the Purine Selection Pattern of *ADSL* Gene Variation in Thai indigenous and Local Chicken Breeds and Red Junglefowls in preparation of the manuscript

Challenges/Problems and Possible solutions:

This study delves into the ecology, genetics, and nutrition of Thai native chickens, exploring their movement, distribution, and adaptation to heat, stress, and local environments. The study uses genomic and nutritional analyses of meat and eggs to identify unique health benefits and compare them to commercial breeds. By sharing knowledge and collaborating with communities and industry, the project aims to empower sustainable native chicken farming and cultivate future researchers.

Future plan:

The study will collect ecological and genetic data, analyze nutritional properties, and compare allergens between native and commercial chickens. Knowledge gained will empower communities, and future plans include establishing breeding programs, promoting niche markets, and developing educational programs. Additionally, AI-powered tools, bio-based products, and cultural heritage preservation will be explored.

Development of Postmasters and Postdocs with a University and Agricultural Industry Network System to Apply Bio-Circular-Green (BCG) Economy for Soil Resource Rehabilitation in Economic Crop Production of Thailand

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Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 20-50%

Abstract:

This project is geared towards strengthening manpower to support the bio, circular, and green economy (BCG) policy in 8 agricultural private sectors related to rice, maize, oil palm, coffee, and mining industries. It aims to develop human capacity with university-private sector networks and strategies for assessing the impacts related to industrial economic crop production for driving the BCG policy. The goal is to enhance understanding of the effects of soil management on soil processes, changes in soil health, and carbon emissions/mitigation and ecosystem services. This, in turn, will contribute to the efficient use of soil resources, aligning with the BCG policy and sustainable development goals, with a focus on the efficient utilization of resources in the agriculture of the country's private sectors.

Rationales/Problem statements:

The BCG policy implementation is driven by the interconnectedness of soil-related resources, encompassing aspects of food security and safety while addressing global challenges such as climate change. Despite concerns among manpower and researchers, the initiative aims to achieve the BCG policy and enhance crop production. The project aligns economic and social policies with natural processes and soil health indices to promote environmentally friendly agriculture. The core of the initiative is to establish a research network among leading Thai agricultural universities—Kasetsart University (KU), Khon Kaen University (KKU), Maejo University (MJU), and Prince of Songkla University (PSU). Collaboration with private sectors in key industries aims to cultivate postgraduate and doctoral researchers, contributing to both national and international research efforts.

Objectives:

1. To enhance the capabilities of postgraduate and doctoral-level researchers in the field of soil and agricultural resource development.
2. To establish a network system among educational institutions and industries for the development of human resources or experts in soil resources, aligning with Thailand's BCG policy on an international scale.
3. To foster innovation in soil-plant resource management for the implementation of the

BCG policy in the country's agricultural production and agro-industrial sectors.

Progress/Findings/Results: Currently, the project has been for 3 months and focused on enhancing the expertise of one postdoc and seven postmasters for implementing the Bio-Circular-Green (BCG) economy in Thailand's leading agricultural private sectors, this initiative, led by 4 Thai agricultural universities and 8 leading companies aim to deepen insights into soil management impact on processes, soil health, and carbon emissions with currently at 20-50% progress depending on subproject. Some findings will be presented in the subproject progress report (poster).
Conclusion: Overall projects are in progress and ongoing data collection with 20-50% of the progress
Current Output: Certainly, the research is currently in progress and ongoing.
Challenges/Problems and Possible Solutions: Insufficient funding for research management is a challenge. The subproject requires initial seed funding dedicated to conducting specific research aimed at addressing issues, as opposed to relying solely on company-sponsored support. The possible solutions involve scoping works within the current support budget and exploring grants to sustain future plans.
Future plan: The ongoing research endeavors to comply with the current objectives. We also aim to expand collaborations to include other private sectors interested in developing solutions and scaling up potential projects for a higher impact.

Development of Frontier Post-graduate Researchers in Systems Microbiology for Prebiotic and Synbiotic Product Development

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Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 30%

Abstract:

This project seeks to explore the potential of systems biology in examining Green Caviar and mulberry extracts while developing two postdoctoral and one postmaster researchers. Two postdoctoral researchers are involved in metagenome analyses of fecal samples treated with the extracts to explore the extracts' prebiotic potential; the analyses are underway. The postdoctoral researchers also set up experiments to assay for the transcriptional responses of *Helicobacter pylori* treated with the aforementioned extracts. The chemical compositions of the extracts were examined by the postmaster researcher using LC-MS-based metabolomics. The experimental design of the bacterial intracellular metabolite extraction was also validated with the metabolome analysis. The project is on track, and the industrial partner will be more involved with the training in the future.

Rationales/Problem statements:

All About Extract Co. Ltd., a pharmaceutical and healthcare retail business, has collaborated with our research team to explore the potential of systems biology in examining Green Caviar and mulberry extracts. The goal is to develop functional ingredients to promote microbial balance and good digestive health. Previous studies have demonstrated that mulberry extract possesses prebiotic properties, fostering the growth of beneficial bacteria. Other studies revealed interesting biological properties of Green Caviar, such as exhibiting antioxidant properties and inhibiting specific pathogenic bacteria like *Helicobacter pylori*. However, in developing functional ingredients, our research team recognizes the significance of understanding the mechanisms of the extracts in inhibiting *H. pylori*-induced gastritis/ulcer. This information is crucial for registering products with specific properties, presenting an excellent opportunity to further explore the realms of prebiotics and synbiotics using holistic approaches or multi-omics technologies, including metagenomics, transcriptomics, and metabolomics.

Objectives:

1. To cultivate postdoctoral researchers while conducting research in the Agriculture and Biotechnology industry, focusing on the first S-curve (Agriculture and Biotechnology).
2. To evaluate the prebiotic properties of Green Caviar seaweed and mulberry by

studying changes in microbial populations in fecal cultures treated with the extracts using metagenomics.

3. To elucidate the inhibitory mechanism against *Helicobacter pylori* of extracts from Green Caviar seaweed and mulberry by transcriptomics and metabolomics.

Progress/Findings/Results:

Green Caviar and mulberry extracts were prepared; the former was formulated with and without maltodextrin encapsulation. The extracts were preliminarily tested with bacteria, including *Escherichia coli*, Streptococci, and Staphylococci, to test the experimental setup in a 12-well plate format. The extracts' inhibitory effects against *Helicobacter pylori* ATCC 43504™ were tested; significant inhibition was found with Green Caviar extracts. As a result, the concentrations for downstream examination (metabolomics and transcriptomics) were decided. The inhibitory effect of the mulberry extract will be re-evaluated as we previously used the synbiotic mix for the preliminary assay – the probiotic growth might interfere with the growth measured by OD_{600}.

In subprojects 1 and 3, the postdoctoral researchers were taught the principles of systems biology, emphasizing metagenomics and transcriptomics. After the training sessions, the postdoctoral researchers attempted to collect samples and extract genomic DNA from fecal samples. Currently, they are working on identifying the treatment concentrations of the extracts (Green Caviar and mulberry extracts). The aim is to determine the concentrations that impede metabolic pathways but do not completely kill the *H. pylori* cells. The sample treatments will be applied when performing transcriptome analysis.

In subproject 2, the postmaster researcher was taught to collect metabolome samples with different methods – bacterial cells grown on agar plate vs. liquid cultures. The postmaster was shown to analyze the samples using the UHPLC-MS system. The resultant metabolome data were analyzed using an open-source software, MAVEN; the postmaster was trained with actual samples to analyze the non-targeted metabolome data. In the first round, the researcher analyzed the chemical compositions of the Green Caviar and mulberry extracts. Further, the intracellular metabolites of *H. pylori* (non-treated) and the *Escherichia coli* control were analyzed to confirm the effectiveness of the extraction procedures.

Conclusion:

The chemical compositions of the Green Caviar algae and mulberry extracts were examined using LC-MS-based metabolomics. The working concentrations of the extracts exhibited inhibitory effects against the bacterial pathogen *H. pylori*. Ongoing experiments will provide the metabolic and transcriptional responses of the extract-treated pathogens. The metagenome analyses of the fecal cultures are underway.

Current Output: prototypes of Green Caviar extracts and mulberry extracts (the latter is in the form of synbiotic mixes); metabolome data (chemical compositions) of the Green Caviar and mulberry extracts (from subproject 2).

Challenges/Problems and Possible solutions: -

Future plan:

We are on track with the research plan. Currently, the postdoctoral and postmaster researchers are trained to perform benchwork and omic-data analyses. We plan to get more involved with the industrial partner once we make more significant progress.

Researcher Development Program for Transcranial Direct Current Stimulation via Telerehabilitation in Individuals with Neurological Deficits

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 65%

Abstract:

People with spinal cord injury (SCI) has several barriers to access rehabilitation center after discharge. Telerehabilitation is a strategy that can provide treatment from remote locations. Our postdoc has been trained to provide telerehabilitation (home-based exercise with transcranial direct current stimulation (tDCS)) via online video calling. Fourteen participants were recruited in this study and then randomly allocated to either active-tDCS (n=7) or sham-tDCS (n=7) group. Participants were trained to apply tDCS by themselves, and then tDCS was given to participants to use it at home. tDCS was applied for 20 minutes before an-hourof exercise for 3 day/week for 4 week (12-session). Outcomes measures (upper limb muscle strength, functional activity, and quality of life) were on-site assessed at pre-, post-intervention and 1-month follow-up. The results showed that upper limb muscle strength was improved in the active-tDCS group compared to baseline. However, this should be confirmed with a larger sample size.

Rationales/Problem statements:

SCI can cause paralysis and functional disability. After discharge from acute care setting, some patients cannot access rehabilitation center due to barriers in economic burdens, transportation, and remote locations. Telerehabilitation is a one strategy that propelled ways for a delivery of rehabilitation from remote locations. Motor and functional training via teleconsultation significant improvements in functional activity after SCI. However, only training may not be able to promote full recovery. A combination of training with brain stimulation techniques may be an option that could promote motor recovery after SCI. tDCSis a non-invasive brain stimulation technique that is used as an add-on treatment in neurorehabilitation. Anodal tDCS (facilitating) over the primary motor cortex (M1) has been shown to increase neural activity at both cortical and spinal levels. Home-based tDCS is safe, accessible, convenient, and scalable compared to hospital-based tDCS.

Objectives:

To develop and train a researcher to be expert in using home-based tDCS combined with telerehabilitation exercise program in individual with spinal cord injury and to explore the effect of anodal tDCS combined with homed-based exercise in people with SCI.

Progress/Findings/Results

Postdoc-researcher has been trained to be familiar with tDCS and tele-rehabilitation program. After ethical approval by MU-IRB, and registration the study at ClinicalTrials.gov (ID NCT06079138), the study was begun in July 2023. Fourteen participants were recruitedin this randomized control trials and randomly allocated to either active-tDCS (n=7) or sham-tDCS (n=7) group. Anodal tDCS was administered over the M1 lower-limb motor area at anintensity

of 2 mA for 20 min in the active-tDCS, while the sham-tDCS group received a 30-s stimulation. Both groups received 1-hour of homes-based exercise after tDCS session for 3 day/week for 4 week (12-session). Both tDCS and exercise sessions are supervised by physical therapist via online video calling. Upper limb muscle strength, functional activity and quality of life are outcomes measures, which were on-site assessed at pre-, post-intervention and 1-month follow-up.

The preliminary results showed that 12-session of home-based tDCS combined with telerehabilitation exercise program significantly improved upper limb muscle strength in the intervention group compared to baseline at post-intervention in individuals with SCI.However, there are non-significant differences for other outcomes. The current data was notsufficient to analysed post-effect at 1-month follow-up. Research is still ongoing to achievesample size plan (n=30).

Conclusion: The current preliminary results appear to show a benefit of home-based tDCS with exercise on improvement of the upper limb muscle strength. However, this should be confirmed with a larger sample size.

Current Output:

1) Postdoc researcher hasgained the knowledge and skills in telerehabilitation.
2) We gained knowledge about possibility of performing telerehabilitation using brain stimulation with home-basedexercises in Thailand.

Challenges/Problems and Possible solutions:

Insufficient participants in the study. More advertisement is required to reach more recruitment to achieve the targeted sample size.

Future plan:

Continuous collecting data until reaching the targeted sample size and then publish the results in international publication (Q1). The results would pave a way to future developing telerehabilitation programs in individuals with neurological deficits in Thailand.

Integrated Biomedical Informatics for a Healthy Life and Well-being in the 21st Century

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 50%

Abstract:

The I-BIC's Integrative Biomedical Informatics for the 21st Century project, Phase 1, focuses on using information, such as simulation and model docking techniques. Eight companies are participating in the project in 11 Sub-projects covering medical health, agriculture, and food. The project progressed well during the first six months of implementation (April 1 to September 30, 2023; 50% Complete). The data for analysis has been collected in total. Moreover, the project has also organized workshops for researchers on using simulation and docking programs. The collaboration with industry partners has been smooth, and no insurmountable obstacles have been encountered.

Rationales/Problem statements:

The Integrative Biomedical Informatics and Computational Imaging Center (I-BIC) collaborates with researchers in various fields to develop knowledge and promote innovation in medical health, agriculture, and food. Specifically, the center aims to (1) Track health status, (2) Promote agriculture and food for healthy and sustainable living, and (3) Develop the potential of young researchers to use computer advances in their research fields.

The I-BIC's Integrative Biomedical Informatics for the 21st Century project uses information, such as simulation and model docking techniques, to study medical health, agriculture, and food. The project has the expertise of mentor researchers to create knowledge, prototypes, and intellectual property by working with industry partners, covering the following:

- Microbial activity on agriculture technology: finding/ discovering the potential of microorganisms or bioactive compounds
- Food and functions: studying the model level of the mechanism of action, making their use more efficient and targeted
- Medical Technology: development of a platform to track health status for prevention and control of disease.

Objectives:

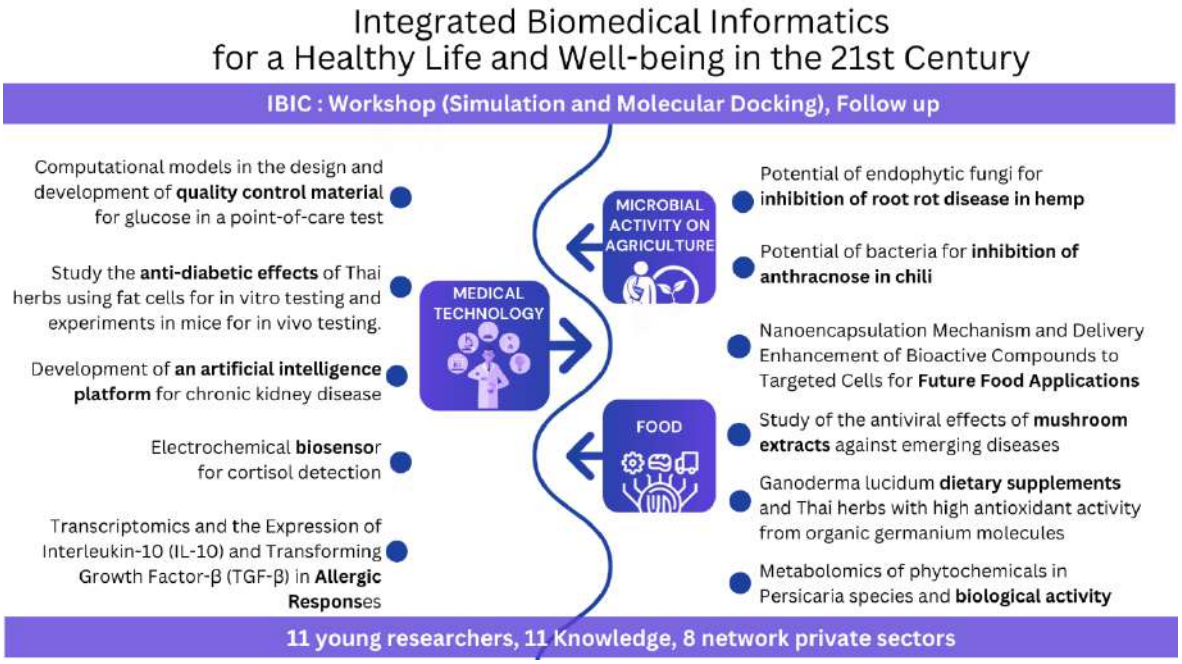
3.1 To integrate and analyze complex biomedical data from various sources.

3.2 To use computational tools and techniques to analyze and interpret scientific data.

3.3 To create continuing education and training programs for researchers and healthcare professionals in biomedical informatics and computer imaging.

3.4 To promote interdisciplinary research from all sectors to ensure that the lives and health of people in the 21st century are smooth and sustainable

Progress/Findings/Results:



Conclusion:

The Integrative Biomedical Informatics for the 21st Century project, Phase 1, has achieved its objectives. The project has progressed in all sub-projects, and the collaboration with industry partners has been positive. The project can significantly contribute to medical health, agriculture, and food.

Current Output:

Prototypes (Under preparation of IP) and draft manuscripts

Challenges/Problems and Possible solutions:

The Integrative Biomedical Informatics for the 21st Century project is scheduled to submit 8 articles for publication. However, most of these articles are still in progress, and there is a risk that they will not be completed by the deadline of March 31, 2024. Therefore, it is necessary to accelerate the writing of the draft articles in the final stages of the project.

Future plan:

The prototype/knowledge will be contributed to publication or patent in the short term. In the second year, these works will be promoted to technology transfer.

Systems and Stratified Medicine Postgraduate Training Program in Phenomics Technology for Medical, Nutritional and Pharmaceutical Industries (STRATiGRAM)

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Project duration: 1 Year, from 1 August 2023 to 31 July 2024
Current progress: 35%

Abstract:
Recent advancements in science and technology have given rise to the emergence of tools tailored for the analysis of extensive molecular datasets, often referred to as Molecular Big Data. This demands a specialized skillset in data analysis, a proficiency currently in short supply in Thailand.
Khon Kaen University stands uniquely prepared to address this knowledge gap, boasting a cadre of highly qualified personnel with doctoral degrees obtained from renowned international institutions. In addition, the institution is home to the Khon Kaen University Phenome Center, outfitted with cutting-edge research equipment. The Phenome Center not only contributes significantly to training and advancing research and innovation capabilities in the realm of Phenomic Mediciqne but also aligns with the impending era of phenomic medicine in Thailand. This alignment involves the adept handling, analysis, and interpretation of extensive and intricate biological data. Furthermore, the Phenomics Center collaborates with industry partners to conduct research and development endeavors, with the ultimate goal of producing products harnessing phenomics technology that align with the principles of the BCG Economy.

Rationales/Problem statements:
In the contemporary landscape of healthcare, Precision Medicine demands a level of precision and specificity surpassing that of general medical services. An indispensable facet of this endeavor lies in Genomic Medicine, where healthcare professionals harness genetic and specific data. Nevertheless, genomic data, in isolation, may not comprehensively address treatment, prevention, and disease surveillance, primarily due to the intricate interplay of genetics and environmental factors. Consequently, the utilization of phenomics technologies or post-genomic data becomes imperative. Given the inherent variability within such datasets, research in Computational Medicine assumes paramount importance. Computational Medicine is predicated on the application of computational science and modeling to simulate the operations of diverse systems within the human body facilitating the development of quantitative methodologies for investigating disease mechanisms, diagnostic techniques, and highly personalized and secure treatment modalities. This initiative aims to cultivate advanced competencies in these domains within Thailand, anticipating the imminent surge in post-genomic era.

Objectives:
1. To increase number of high caliber postdoctoral and postgraduate researchers with phenomics knowledge and skillset in Thailand.
2. To generate knowledge, research, and academic contributions driving the development of research infrastructure and innovation in the field of phenomics in Thailand.

Progress/Findings/Results:
Postdoctoral researchers and postgraduate researchers have been trained through short

courses that were conducted by experts at Khon Kaen University Phenome Centre, including phenomics short course for 15 days (during October 2–16, 2023) and high-throughput technology and data safety (Hi-Tech-DS) short course for 5 days. Moreover, they also attended the Thailand Bioinformatics Research Network (TBRN) meeting in Bangkok on October 10, 2023. After the training, they started academic services of Khon Kaen University Phenome Centre with its clients. Apart from that, they also met with their research mentor to discuss and start their research projects. Moreover, the postdoctoral and postgraduate researchers are required to submit a monthly progress report to the principal investigator.

Conclusion:

The progress is in accordance with the plan. During the first two weeks, postdoctoral researchers and postgraduate researchers were trained in a phenomics short courses, and after training, they started their research projects with their research mentor. They have been very welled equipped with the essential phenomics skillset.

Current Output:

1. Trained postdoctoral and postgraduate researchers in phenomics skillset and

Challenges/Problems and Possible solutions:

During the training period, some postdoctoral and postgraduate researchers dropped out along the way due to incompatibility, incompetency or unparallel preferences. Our solutions are 1) calling up the researchers on our interview waiting list for replacement and 2) early detection of incompetency or unparallel preferences of researches through observation and frequent evaluation.

Future plan:

The postdoctoral and postgraduate researchers will undertake phenomics skillset half-way evaluation. Moreover, they will also serve as teaching assistants in Multi-Omics short course during 22 January – 2 February 2024 and also completion of their research project to produce Q1 publication and/or IP (depending on individual's terms and conditions).

Pharmaceutical Innovation for Health Product Development and Active Aging Society

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Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 45 %

Abstract:

Pharmaceutical innovation is very important for product development, especially for the aging society. In the present study, we aimed to develop the melatonin oral gel and lycopene noisome dosage forms. Melatonin (MLT) has various biological activities such as antioxidant, anti-inflammatory and wound healing properties. 4-Bromobenzoyl melatonin (BBM) and 4-Bromo ethyl benzamide-5-methoxyindole (EBM). We found that MLT and its derivatives exhibited the wound healing activity. Lycopene niosome formulations from tomatoes, carrots, and red vegetables made using thin film and microfluidic method incorporated into preparations were developed for topical applications. Lycopene-niosome formulations display sustained control of lycopene release. All formulations showed morphology that presented vesicles found in a spherical unilamellar structure with a homogenous particle size and a smooth boundary. In addition, we also found that we found that CMS significantly increased anhedonia and depression-like behavior and mice treated with GN resin extract showed a significantly decreasing of depressive behaviors.

Rationales/Problem statements:

Thailand's ageing demography is a growing concern, which, if not handled properly could deal long-term structural blows to the economy of the kingdom. Now more than ever, it should be high up on the priority list for the government to address. In addition, depression in the elderly community is a common problem. Therefore the present study was aim to develop the pharmaceutical products that will be used for the elderly people such as the melatonin oral gel and lycopene noisome for nutraceutical purpose. We also plan to investigate the effect of *Garcinia nigrolineata* resin extract (GNRS) on antioxidant activities, MAO inhibition and depressive-like behaviors Induced by CMS mice model. If the results exhibit the great potential of GNRS for development as the anti-depressive agent, we will plan to continuing study.

Objectives:

1. To investigate the effect of Melatonin and derivatives on wound healing and ex vivo skin permeation
2. To quantitatively investigate and characterize lycopenes according to their vegetable

sources, biological activities, and develop lycopene-niosome preparation methods. Tomatoes, carrots, and red vegetable extracts subjected to a microfluidic method were compared with a thin-film method through physical characterization.
2. To investigate the effect of *Garcinia nigrolineata* resin extract on antioxidant activities, MAO inhibition and depressive-like behaviors Induced by CMS mice model.

Progress/Findings/Results:

1. Both Melatonin derivatives (BBM and EBM) have a potential of wound healing activity greater than melatonin by promoting cell migration on wound area to 99% at 30 hr. In addition, FTIR spectra confirmed that BBM and EBM could permeate from epidermis to dermis layers faster than melatonin.
2. We show the effects of various niosome formulations with lycopene extracts from tomatoes, carrots and red vegetables. Lycopene from these extracts by the microfluidic method should be used in place of those from the thin-film method. Since the fewer steps are required, making the former process more suitable for industrial niosome production. Moreover, this technique also has greater uniformity, homogeneity (low PDI value), and precise management of niosomes with a smaller size. Additionally, all lycopene from these extracts provided sustained release. Lycopene-niosome formulations were applied as a topical product.
3. We also found that CMS significantly increased anhedonia and depression-like behavior when compared with the vehicle-treated non-stress group. Mice treated with GN resin extract showed a significantly decreasing anhedonia-like behavior on sucrose preference and depression-like behaviors on TST and FST as same as imipramine. This enhancement could be reversed by long-term treatment of GN resin extract as well as by imipramine.

Conclusion : Melatonin and derivatives exhibited the wound healing and ex vivo skin permeation activities. Lycopene niosomes that were prepared by using microfluidic method can be used in place of those made using a thin-film method. The microfluidic method requires fewer process steps. Both of these products are beneficial in developing industrial niosome production processes to produce material for topical applications.In addition, daily administration of GNRS to CMS mice ameliorated both anhedonia, by increasing 2% sucrose intake, and hopeless behavior, by reducing immobility times in the forced swimming test (FST) and tail suspension test (TST). The multiple antidepressant actions of GNRS emphasize its potential as an effective, novel treatment for MDD.

Current Output: Lycopene noisome prototype.

Challenges/Problems and Possible solutions: -no

Future plan:

<u>Melatonin derivatives (BBM and EBM)</u>

- ❖ Product development of melatonin and its derivative for oral gel dosage form will be performed

<u>Niosome Lycopene Development</u>

- ❖ Study the pharmacological activity of lycopene noisome in cell culture as UV-B protection, antityrosinase activity and inhibitory effect on melanin production.

<u>Antidepressant activity of GN resin extract</u>

- ❖ Further studies are needed to clarify this possible mechanism by assessment of related gene expression on RT-PCR.
- ❖ Determination of CORT serum levels in order to clarify the molecular mechanism.

Talent Development for University Innovation Driven Enterprise (University Spin-off Program) or T4Ent

Chulalongkorn University
*E-mail: Principal Investigator

Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 20%

Abstract:

Enhancing the capabilities of a highly skilled workforce is a crucial tool in propelling a country forward, increasing its competitiveness, and advancing society. With the goal of unlocking Thailand's potential and transitioning into a developed nation, the National Higher Education, Science, Research, and Innovation Policy Council (NXPO) has set objectives to increase the number of high-revenue Innovation-Driven Enterprises (IDEs) to 1,000 companies, each generating more than 1 billion Baht in annual revenue. This initiative aims to contribute a total GDP value of over 2 trillion Baht and create high-income employment opportunities. To achieve these goals, there is a push to establish University Holding Companies as separate legal entities from universities. These entities, functioning as dedicated business units, are tasked with investing in professional innovation businesses. This involves strategically managing investments in the research activities of emerging entrepreneurs, enabling the expansion of research outcomes into commercial ventures through the establishment of spin-off businesses.

Rationales/Problem statements:

The goal of establishing companies with high growth rates or significantly scaling up, which will contribute to GDP growth, should be pursued through three strategic dimensions: Talent Management Strategy, Ease of Scaling-Up Strategy, and Availability of Funding Strategy. To address the challenges in Thailand, where entrepreneurs may lack experience and suitable characteristics for innovation-driven businesses, policies should focus on attracting high-skilled talent, both local and international.

Encouraging the development of new-generation entrepreneurs with scaling-up potential, supporting funding for skill enhancement throughout the system, and enhancing the capabilities of the workforce in targeted industries are essential objectives. Recognizing universities as hubs of high-potential researchers and innovators, Chulalongkorn University has initiated the development of an incubation and investment support system for innovation-driven businesses with researchers and staff as entrepreneurs, facilitated through the University Holding Company mechanism. This has resulted in successful models of IDEs that have successfully raised funds, positioning them to contribute to the country's development.

The exchange of experiences and knowledge transfer to other educational institutions has also been initiated to build entrepreneurial skills among researchers and innovators. This involves creating dedicated teams with genuine intentions, fostering a culture of innovation, setting global aspirations, promoting open-minded thinking, and working collaboratively across disciplines and institutions to genuinely meet the needs of the global market and society.

Objectives:

1. Create innovative leaders with entrepreneurial skills (CEO/CTO) (Demand-driven)
2. Develop a business based on deep innovation (Deep-tech) with science and technology.
3. Create an ecosystem to support the establishment of startup enterprises in universities (University Spin-of).

Progress/Findings/Results:
After the StartIDEs & SpinIDEs project has been promoted. This project received a positive response. The project coordinator has been contacted by researchers both within and outside Chulalongkorn University who are interested in joining the project.
The project has progressed to the practical training phase, commencing with the inaugural session held on December **6**th, **2023**, covering the topics "Welcome to IDEs Ecosystem" and "Hello Customer." Participants actively engaged in the session and collaborated effectively with the instructors.
Conclusion:
The training curriculum aims to integrate insights from international innovation ecosystems, emphasizing the promotion of knowledge, skills, and attitudes that enable researchers to effectively translate research and innovation outcomes into both societal and commercial benefits. Additionally, participants will have the opportunity to receive support for incubating and accelerating innovative businesses through the university's Innovation-Driven Enterprises (IDEs) mentoring network. This involves listening to experiences from speakers, hands-on application of new business management tools, exchanging knowledge with training cohorts, and receiving coaching support to empower entrepreneurs.
Current Output: Research report
Challenges/Problems and Possible solutions:
Due to the cancellation of the contract with the project, as the researchers were unable to continue their work, there were some gaps in the project's progress. To address this issue promptly, the project is expediting a resolution by bringing in new researchers to replace the previous ones. This is aimed at ensuring the project can achieve its objectives in a timely manner.
Future plan:
In the next phase, the project will divide researchers into groups to train them in the pitching process, aimed at developing skills for presenting the business to participants. The training sessions are scheduled for December 28, 2023, and January 31, 2024. Researchers will be required to summarize the progress of their work over the 6-month period.

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ด้าน Research Infrastructure

Medical Imaging Standard Datasets Development for Research and Innovation in Artificial Intelligence, Faculty of Medicine, Ramathibodi Hospital

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Project duration: 1 year, from 24 April 2023 to 31 March 2024

Current progress: 30%

Abstract:

Artificial Intelligence (AI) is extensively utilized, including in the analysis of medical data, which necessitates the development of AI models using significant data volumes to achieve effective outcomes. The project for an open medical data management platform aims to bolster Thailand's AI capabilities through the collaboration of the Department of Medical Services, the National Science and Technology Development Agency (NSTDA), and the Faculty of Medicine Ramathibodi Hospital, Mahidol University. This initiative entails collecting medical data from various hospitals, anonymizing personal information, categorizing, and curating datasets to align with medical diagnoses, and providing processed datasets for AI applications. The datasets are presented into two categories: one for public sharing and another for the development of AI engines or models by consortium members, adhering to the consortium's guidelines. Ramathibodi Hospital is currently compiling image data from five target disease groups: lung diseases, cerebrovascular diseases, breast cancer, prostate cancer, head and neck cancer, and osteoporosis. Efforts are underway to develop data anonymization programs, establish data standards within the consortium, and work on data annotation/labeling, AI model development, and the creation of a conducive ecosystem for AI research and innovation. To date, 15,590 medical images have been verified, and 33,600 images from 10,100 studies have been annotated in conjunction with the software development for data anonymization and the setting of data standards. Moreover, we are conducting AI training for interested staff and formulating guidelines to establish a Medical AI Consortium at the Faculty of Medicine, Ramathibodi Hospital.

Rationales/Problem statements:

Artificial Intelligence (AI) is extensively utilized, including in the analysis of medical data, which necessitates the development of AI models using significant data volumes to achieve effective outcomes. The project for an open medical data management platform aims to bolster Thailand's AI capabilities through the collaboration of the Department of Medical Services, the National Science and Technology Development Agency (NSTDA), and the Faculty of Medicine Ramathibodi Hospital, Mahidol University. This initiative entails collecting medical data from various hospitals, anonymizing personal information, categorizing, and curating datasets to align with medical diagnoses, and providing processed datasets for AI applications.

Objectives:

- To create imaging datasets from Ramathibodi Hospital's existing data for the further development of in-house AI, including for research and clinical applications, and to create public datasets to support the growth of medical AI in Thailand.

- To develop economy system for Artificial Intelligence and to bolster collaboration
- To develop Artificial Intelligence skill for personnel

Progress/Findings/Results:

The research project is under data collecting process and development of a standardized dataset encompassing medical images within specific disease categories, notably prostate cancer, breast cancer, and head and neck cancer, as well as conditions such as osteoporosis, lung disease, and stroke. The research holds ethical approval for human research and has implemented a program ensuring non-disclosure of information. This involves the deletion of personal data in compliance with DICOM Part 15 (P.S. 3.15)**,** Appendix E specifying the confidentiality profile, and adheres to the principles outlined in the Personal Data Protection Act (PDPA) of Thailand and the Health Insurance Portability and Accountability Act (HIPAA) of the United States.

A system has been developed to establish a linkage between image data and crucial clinical information through the utilization of anonymization programs, employing hashing keys. This progress has reached a completion rate of 40%. Additionally, efforts are underway to standardize datasets based on anatomical pathology, labeling abnormalities using standard dictionaries derived from existing standards such as SNOMED, RadLex, and ICD, which will be stored in The Observational Medical Outcomes Partnership (OMOP) Common Data Model (CDM). There is ongoing progress in the data standardization across individual projects.

In a collaborative effort with the NSTDA, Ramathibodi Hospital has co-developed an annotation tool, which is now in its developmental stage.

Additionally, the groundwork is being laid for Memorandum of Understanding (MOU) documents, including agreements among Ramathibodi Hospital, the Department of Medical Services, and NSTDA. These agreements, which comprise Data Sharing Agreements (DSA) and Data Processing Agreements (DPA), are crucial in establishing a cooperative framework.

As part of knowledge enrichment, the project has been proactive in inviting speakers, both internal and external to the institution, to share insights and expertise in the field of AI particularly in the realms of data and AI governance. This approach is intended to cultivate a broad and enlightened viewpoint that will propel the objectives of the research project forward.

Conclusion:

The Research project is in the progress

Current Output:

15,590 medical images have been verified, and 33,600 images from 10,100 studies have been annotated in conjunction with the software development for data anonymization

Challenges/Problems and Possible solutions:

As AI ethics continue to evolve within Thailand, and their novelty necessitates a meticulous and cautious approach to prevent potential future consequences. This cautious stance has led to a delay in the initial implementation phase. To navigate these intricacies, the project has engaged with domain experts from both within the institution and the wider community. Their insights are crucial in guiding the project towards an efficient and accurate execution aligned with the established principles of ethical practice.

Future plan:

- Compilation of **36,740** medical studies, comprising over **628,000** images, thoroughly verified, or annotated by radiologists. This dataset is eligible for public sharing under the consortium agreement.
- Development of pilot models designed for diagnosing conditions or interpreting results

obtained through the analysis of AI from meticulously prepared testing data.

- Formation of the Ramathibodi Medical AI Committee.
- Initiation of a Radiology-Data Science course.
- Establishment of a collaborative network encompassing developers and companies engaged in the advancement of AI within the medical field, adopting a consortium-type structure.

Open Medical Data Platform Development for AI-driven Research and Development and Innovation in Thailand: Initiating the Medical AI Consortium and Developing the Central AI Platform

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 65%

Abstract:

This project initiated by the medical AI consortium aims to develop a medical data-sharing platform to strengthen collaboration in the development of an artificial intelligence ecosystem for healthcare. The initiative begins with three organizations: (1) Department of Medical Services, Ministry of Public Health, (2) Faculty of Medicine Ramathibodi Hospital, Mahidol University, and (3) National Electronics and Computer Technology Center (NECTEC), National Science and Technology Development Agency (NSTDA)

The medical data-sharing platform consists of four main components: data collection, data catalog, data governance, and data annotation tools. The platform adopts the metadata design defined by The Cancer Imaging Archive (TCIA) website to ensure data accessibility and security. The data sharing level on the platform provides the basis for the data governance framework by classifying data into four levels: private data, anonymized data, conditional shared data, and public data. The platform is built on top of the CKAN Open-D data catalog platform developed by NECTEC and initially supports image data formats including DICOM file formats, general image files, such as JPG and PNG, and plan to support common standard data annotation formats such as MSCOCO, Pascal VOC and YOLOv8. Currently, the data annotation tools are in the design process.

Rationales/Problem statements:

Medical image data and annotation data are imperative for medical AI system development such as medical screening and diagnosis system. This project resolves those by developing the data governance framework and platform for sharing medical data. Having a solid data governance framework provides guidelines for organizations in the consortium in management and sharing of sensitive data efficiently and securely. The medical image data sharing platform development involves designing and adopting related data standards such as metadata standards for data catalog, data classification levels, medical image data formats, and data annotation standards.

Objectives:

1) To design and develop data governance framework for medical data sharing
2) To design and develop medical data sharing platform
3) To provide data tools to support browsing and annotation of medical data
4) To establish the Medical AI Consortium

Progress/Findings/Results:

Metadata design for data catalog of published datasets is based on the metadata fields defined by The Cancer Imaging Archive (TCIA) website (https://www.cancerimagingarchive.net/). The metadata fields consist of nine metadata fields: dataset name, description, disease type, body part, number of patients, data type, access level, status and updated. Defining such metadata standard ensures datasets that are shared and published on the platform are

uniformly searchable. This will help users to efficiently discover the required medical image datasets and use them for the intended purposes.

Data sharing in the platform is based on four classification levels: private data, anonymized data, conditional shared data and public data. Private data includes datasets that only owner organizations of the datasets can access. Anonymized data include datasets that are shared only among organizations who are members of the consortium. Conditional shared data includes datasets that are shared with the organizations outside of the consortium. Public data include datasets that are publicly accessible. By defining such data classification levels, medical image data can be shared securely and provides the basis for data governance framework for the platform. The medical image data sharing platform has been developed using the CKAN Open-D data catalog platform developed by NECTEC.

Data annotation standards, tools and guidelines for the data platform are currently in the design process. Examples of tools under study include Label Studio, LabelMe, and VGG Image Annotator, which are designed for a variety of tasks, and Annotation Tool, which was used in the RAMA AI project designed for lung X-ray images. Next phase operational plan will focus on creating image data storage that can be browsed and accessed by the annotation tools.

In terms of supporting medical data standards, the developed system supports data in both DICOM file formats and general image files (JPG or PNG). DICOM files store data other than the image content as well. We plan to extract only tags that can be used to train AI model, such as tags related to image texture, pixel data, image type, modality, image position, image orientation, and photometric interpretation and tags related to patient characteristics such as patient's sex, age, size and weight, etc.

In terms of data annotation standards, the studied standard data annotation formats include MS COCO, Pascal VOC, and YOLOv8. The key information includes project ID, patient ID, image ID and annotator ID. Data annotation standards and guidelines will be defined for the data platform. This will allow the annotated data to be published and shared in a uniformed way and supported by the endorsed data annotation tools.

In the administration of the Medical AI Consortium, the signing ceremony for the MOU occurred in August 2023. Concurrently, a comprehensive management framework, comprising guidelines and committee regulations, has been developed including collaboration with other organizations to join the consortium.

Conclusion:

In this project, a data governance framework and a platform for medical image data sharing are being developed. The related standards such as metadata standards for data catalog, data classification levels, medical image data formats, and data annotation standards are designed and adopted for the platform using the CKAN Open-D data catalog platform.

Current Output:

A prototype of medical image data sharing platform

Challenges/Problems and Possible solutions:

The technical challenges include designing and adopting related data standards such as metadata standards for data catalog, data classification levels, medical image data formats, and data annotation standards. Additional challenges include providing data tools and guideline to support the data users such as data anonymization and annotation tools**.**

Future plan:

Next phase of the development will focus on integrating various data tools such as image data storage, annotation tools, and defining data annotation standards and guidelines. Additionally, it will focus on deploying the medical data sharing platform and collecting unannotated and annotated medical image data from the organizations who are members of the consortium into the data platform.

Development of Synchrotron Based-Infrared and X-Ray Infrastructure for Supporting and Promoting Community Enterprise, Future Food, and Agricultural Industry

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 76.4%

Abstract:

This project aims to improve synchrotron infrastructure as well as supporting community enterprise, food, and agricultural industry. There are three parts to this project: 1. Industrial service 2. Promoting the synchrotron infrastructure 3. Development of techniques and instruments and infrastructure maintenance. In order to explore the possibility of employing the synchrotron to address industrial problems, fourteen institutes and corporations visited the facility, and seven projects with a service contract have been established. Fabrication is underway for the micro-XRF and micro-XAS system. The system will be tested in February 2024. The installation of the new workstation for XTM techniques was performed effectively. Consequently, huge data that was previously unanalyzable may now be done so, and certain data can now be processed in half the time. Vacuum pump maintenance and UPS unit battery replacement were completed. Two employees get additional expertise in developing new techniques.

Rationales/Problem statements:

The micro-XRF/XAS system's component manufacture faced some delays, but overall, the component is still expected to be ready for testing in February.

The acquisition of equipment from overseas had to be delayed because of expert recommendations for new specifications and negotiations with the corporation to secure additional licenses for the software.

Objectives:

1. To develop techniques and tools with synchrotron light analysis as a national laboratory for food and agriculture.
2. To serve as an infrastructure for the development of food, agricultural, and other related products, empowering entrepreneurs to compete in national and worldwide markets while enhancing economic value through synchrotron light technology.
3. To establish a collaborative network between The Synchrotron Light Research Institute and government agencies such as the Thailand Science Park and Thailand Central Laboratory. This collaboration will leverage their knowledge and advanced scientific equipment to provide in-depth analysis, increasing the potential and strength of food and agricultural research development.

Progress/Findings/Results:

This project is divided into three sections: 1. Industrial service 2. Promoting the synchrotron infrastructure 3. Development of techniques and instruments and infrastructure maintenance. In order to explore the possibility of utilizing the synchrotron to address industrial difficulties, fourteen firms and institutes paid a visit to Synchrotron Light Research Institute (Public Organization), SLRI , and seven projects with service contracts were formed. A total of ten projects are expected at the end of this project. Production of the micro-XRF and micro-XAS systems is under progress. The system will be installed to test in February 2024. X-ray beam at the sample is expected to be reduced to less than 30 microns (FWHM). The demonstration of XRF mapping as well as micro-XAS with micron beam will be reported.

It was successfully installed the new workstation for XTM beamline. As a result, vast amounts of data that were before inaccessible for analysis may now be done so, and certain data may now be analyzed in half the time. The UPS unit's battery replacement and vacuum pump maintenance were finished. Two workers get more experience in creating novel methods. Additional staff members will be taught to service new techniques for users and will be included in the installation and commissioning process. It is anticipated that three industry researchers and seven graduate students would receive training on how to use the newly constructed and enhanced infrastructure.

Conclusion:

SLRI was visited by 14 companies and institutes related to food, agriculture, energy, drugs, and cosmetics. Seven service contracts for the industrial usage of the synchrotron facility have been signed. The system for micro-XRF/XAS has been designed. The micro-XRF/XAS system has currently been constructed. with testing scheduled for February 2024. The new workstation for XTM beamline was successfully installed. As a result, certain data may now be analyzed in half the time. The UPS unit's battery replacement and vacuum pump maintenance were finished. Staff, graduate students, and industry researchers will gain additional skills as infrastructure and services are developed.

Current Output: Design for micro-XRF/XAS system. Two staffs get more experience in micro-XRF/XAS development.

Challenges/Problems and Possible solutions:

Future plan:

The system for micro-XRF/XAS will be tested in February 2024. Meetings with industry and facilities tours will continue. Researchers from industries and graduate students will be trained to use the facility. More staffs will be involved in the installation and commissioning process and will be trained for user service in new technique.

The Development of Linear Accelerator for Agriculture and Industrial Applications

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 87% (6 months)

Abstracts: The Synchrotron Light Research Institute (SLRI), a public organization, has taken significant strides in developing a linear accelerator (Linac) technology capable of adjusting energy levels 3-6 MeV. This technology is accompanied by systems such as RF sources, utilities, scan horns, conveyor systems, and automatic control systems. These systems exhibit remarkable stability, with an average electron beam power of approximately 1.6 kW at a duty factor of 0.001 and a maximum energy of 6 MeV. This setup enables the use of X-ray mode for research and irradiation purposes. Applications include research into pathogen-free irradiation of fresh fruits with X-rays and vulcanization of raw rubber materials using on a research scale. Each irradiation process tailored to specific products and objectives necessitates the fine-tuning of electron beam parameters, achievable through modifications in the electron beam production system, RF systems, and beam direction through magnetic fields, conveyor system speeds, and irradiation durations. The Linac and all sub-systems have been commissioned at a given electron energy to achieve a good efficient and stable acceleration. This leads to the continuous production of X-rays and irradiation testing to ensure pathogen-free conditions in fruits.

Rationales/Problem statements:

Objectives:

- Design, develop, construct, and test a variable-energy particle accelerator system capable of adjusting electron energy within the 3-6 MeV range, accompanied by a transport system for x-ray irradiation to serve as a central hub for research and development for applications.
- To study and develop knowledge and technology for RF sources, as well as systems for generating electron pulse signals, including pulse-forming networks and solid-state modulators.
- Develop the knowledge, expertise, and skills of engineers and researchers specializing in particle accelerator technology.

Progress/Findings/Results:

The research will focus on developing a tunable energy linear accelerator and testing it for continuous X-ray irradiation in its early stages. The project has undertaken the development and testing of these systems to support the continuous and stable operation of the Linac as follows:

- A centralized control system of the Linac and sub-systems, built on the EPICS framework, has been designed, and both individual and integrated tests have been conducted to thoroughly verify its functionalities.
- The energy accelerated at the Linac exit could be varied in the range of 3.6 – 4.87 MeV by adjusting the RF power fed into the Linac. By employing developed Automatic Frequency Control (AFC), the Linac can dynamically control the frequency of the RF power, ensuring that the electrons experience optimal acceleration conditions.
- To validate the stability of the accelerator system, testing was conducted through X-

ray production successively.

We also designed and developed key components of RF systems such as pulsed modulators, and scan horn to facilitate application with electron beams or X-rays for irradiation. These components were simulated and designed with preliminary results as follows:

- A solid-state pulse signal source for an electron gun and a line-type modulator for a klystron were designed and simulated based on LTspic. The simulations of circuit design using LTspice for the klystron source and electron gun have slightly different values from the designed specifications, but it is acceptable in practical uses.
- Scan horn with Ti-window and W-target as the X-ray converter has been designed and simulated with GEANT4. As a result, the Titanium with 50 μm thickness can transmit all electrons to hit the W-target. The optimized W thickness is 1.25 mm achieving maximum X-ray yields and only 0.05% electron leakage.

Conclusion: The project has successfully adhered to its plan, achieving the capability of adjusting the energy to a minimum energy of approximately 3.6 MeV, as measured by the energy measurement system, and reaching a maximum energy of 4.87 MeV. This is still below the designed energy level due to frequency fluctuations in the high-power RF, causing deviations beyond the control range of the magnetron's AFC system. This issue is currently being addressed by improving the motor control and tuning the position of the magnetron's frequency to respond more quickly. Additionally, the project has implemented a closed-loop control system for the cooling water system of the accelerator tube, maintaining the tube temperature at 40 ± 0.2°C during accelerator operation. Subsequently, the project conducted tests on agricultural product irradiation using X-rays as a preliminary study, measuring electron beam properties and X-ray radiation quantities at various energy levels according to the intended irradiation purposes.

Current Output:

- The project participated in the international academic conference, the 15th Vietnam Conference on Nuclear Science and Technology (VINANST-15), presenting a paper through an oral presentation on the topic "The Development of Linear Accelerator for Applications at SLRI" on August 9-11, 2566 (corresponding to 2023) in Nha Trang, Vietnam.
- Progress has been achieved in adjusting Linac energy modulated between 3.6 and 4.8 MeV through precise adjustment of RF power supplied to the Linac, ensuring proper phase and synchronization of the RF frequency. Developing and testing centralized control based on EPICS software, incorporates communication protocols, namely Channel Access and PV Access, specifically implemented to the Linac operation. The utilization of these protocols within the EPICS system ensures smooth and coherent communication among all subsystems.

Challenges/Problems and Possible solutions:

Future plan:

The project aims to conduct irradiation testing on fruits and processed agricultural products to mitigate pathogenic contamination and reduce deterioration. Specifically focusing on fresh fruits, the goal is to determine an appropriate radiation dosage for agricultural health control, including pest management for fruit flies and other plant pests. The irradiation process aims to ensure the safety of consumers while preserving the nutritional quality of the produce. Consequently, there is a commitment to establishing standards for agricultural product irradiation, relying on international ISO standards for ongoing pathogen control. Leveraging the energy adaptability of the accelerator system, the project also pursues avenues to enhance product quality and pathogen control, including the development of expertise in the engineering of RF systems. Additionally, the project will develop a scan horn that can provide two modes of electron and X-ray radiation, facilitating diverse applications.

Development of an Energy-adjustable Beamline and In-vacuum Research Station for Material Analysis using Proton Beam from the Cyclotron Facility (B41G660051)

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 52% of the project plan during the reporting period
(37% of the plan throughout the project)

Abstract:

The preliminary design of the beam transport system, including the energy degrader system and the Faraday cup, was done. The Monte Carlo simulations were performed to characterize the proton beam transport along the beam line. Using the simulation, the appropriate foil thickness of the energy degrader system and proton interaction were also investigated. We will further discuss and optimize the design with the SLRI team before fabricating the prototype. The validation and testing will then be conducted after the prototype is completed. However, some research activities are currently delayed because of the delay of the TINT cyclotron installation project, resulting in the delay in commissioning the cyclotron and getting the proton beam profile as an essential input parameter for the simulation.

Rationales/Problem statements:

Current in-air PIXE and PIGE systems have limited detection sensitivity due to the scattering of X-rays and ions by air molecules. This scattering reduces the intensity of the X-ray beam and the number of ions reaching the sample, limiting the ability to detect trace elements. The development of a new in-vacuum beam line for PIXE and PIGE techniques would provide a significant advancement in elemental analysis capabilities. The enhanced detection sensitivity, micro-beam capability, reduced background noise, and wider range of applications would make this beam line an invaluable tool for researchers and scientists in a variety of fields.

Objectives:

1. To develop a proton transport system and a research station at the TINT cyclotron facility with an energy-adjustable system supporting in-vacuum material analysis.
2. To develop a high-sensitivity analysis system, particularly for trace elements, light elements, and thin film samples, supporting innovative development and serving industries in various fields such as biology, environment, agriculture, food, and materials industries.
3. To enhance professional capacity, potential research of high energy physics technology and opportunities for Thai researchers to access the advanced analytical facility in the country.
4. To be a learning center on the Physics of particle accelerators and enhance the country's competitiveness, especially as a scientific infrastructure.

Progress/Findings/Results:

The preliminary design of the proton beam transport for in-vacuum material analysis, consisting of an energy degrader system, an energy measurement system, an analysis chamber and a beam current measurement, was achieved using SolidWorks. The design is based on the existing beam transport system of TINT cyclotron. The obtained design could

be used to assess the space for a new beamline installation.

Proton beam characteristics along the designed transport system were studied using G4beamline simulations. In the simulation, the initial proton energy of 15 MeV was defined with a beam size of 10 mm in diameter. The simulation showed that the calculated foil thickness could reduce the proton beam energy to reach the target energy of 3 MeV at the end of the beamline. The beam transport system could deliver proton particles to the analysis station with no significant change in proton energy. The collimator and slit could help to limit the beam energy spread and the beam size. However, the beam current decreased due to the use of collimators and slits along the beam line.

In addition, the energy degrader materials such as aluminium and graphite were studied using the SRIM and Geant4 simulation to find the optimal thickness and investigate the beam characteristics after passing through the material foil. The mean proton energy and energy spread were obtained as a function of foil thickness varied from 0.1 – 1.2 mm. In terms of mechanical design, the energy-adjusting system was investigated for three configurations: pneumatic pistons, wedge, and fan. When considering simulation data and the fabrication process, the fan type is most appropriate because it allows changing foil material and adjusting foil thickness up to 8 pieces, making it more flexible.

For the energy measurement system, we have requested the specification of a proton detector system, as this information is useful for designing the energy measurement chamber.

The Faraday cup design as an in-vacuum system was carried out using SolidWorks. The shape of the inside part of the beam collector, which was cone and cylinder, was studied to determine the collecting efficiency, and scattering of protons and secondary electrons using Geant4 simulation. The preliminary results showed that there was no significant difference in the number of escaping protons and secondary electrons at the cup entrance based on the shape of the beam collector.

Conclusion:

We have preliminarily designed the proton transport system and conducted the simulation to evaluate the proton beam characteristics along the beam line. These studies are useful and important for developing the new beamline and end station for material analysis. The material and thickness of the foil and the configuration of the energy degrader were carried out. The design is nearly complete for the Faraday Cup. It is under preparation for fabrication.

Current Output:

- Publication: Poster presentation at the 26th International Conference on IBA and the 18th International Conference on PIXE, Japan on 7 - 13 Oct 2023, the title of design of the beam transport system of cyclotron-based IBA station using Monte Carlo simulation. The manuscript is being prepared to be submitted in January 2024.
- Capacity building: In contact with the University lecturers for the internship program.
- Prototype: The design of the energy degrader and the Faraday cup was almost completed. Fabrication and testing will be continued.

Challenges/Problems and Possible solutions:

TINT has been dealing with technical problems due to the commission of the cyclotron, causing the delay of this project. In the meantime, the research team visited the Princess Maha Chakri Sirindhorn Proton Center, Chulalongkorn Hospital and discussed the opportunity for prototype testing with proton beams from the medical cyclotron. In addition, contacting the dealer regarding the proton detector was not very successful, which therefore impacted the design of the energy measurement system and the procurement of the detector.

Future plan:

- Proceed with the procurement of the detector and the vacuum equipment.
- Fabricate the prototypes and run the prototype testing with proton beams.
- Further optimize the tested system.

Developing on the Service Potential of Center of Ion Beam Materials Development and Optical Analysis (CIMO)

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 65%

Abstract: Primarily, the center is equipped with tools for developing the quality of materials and gemstones, conducting basic gemstone analysis, and utilizing advanced optical analysis. In this project, the laboratory's capabilities have been enhanced with the addition of an FTIR-Microscope to study the functional groups within gemstones, a gemological microscope with an image recording system, and a hydrostatic weighing to meet laboratory standards. The center has established a comprehensive gemstone database and engaged in collaborative research with an international university that employs ion beam and advanced analytical techniques. This collaboration serves as a guideline for developing the laboratory's tool capabilities in the future. Furthermore, the project is actively involved in public relations activities to create awareness among businesses interested in technology, preparing the laboratory to meet standards, and serving as a support service for frontier research, thereby increasing value in the industry.

Rationales/Problem statements: The development of infrastructure is a crucial component that contributes to advancing frontier research. In the process of conducting research and developing databases for gemstones such as rubies and sapphires from various origins, multiple analytical techniques, including elemental composition analysis by LA-ICP-MS and various other methods using advanced optical analysis, are employed. This aims to understand the conditions suitable for enhancing the quality of gemstones by ion beam technology to meet market requirement standards. Furthermore, the skills of the researcher must be developed by engaging in international exchanges and research, studying laboratory management, applying tools and analytical techniques, discussing collaboration avenues with academic institutions abroad, and fostering awareness among researchers and industry stakeholders, it is imperative for businesses to promote and conduct training sessions to transfer technology to the target. The concurrent development of infrastructure along with workforce capacity can enhance the efficiency of frontier research.

Objectives:

1. Developing the potential of the laboratory to meet the standards of a gemological laboratory.
2. Creating a database of gemstone enhancements by ion beam technology and optical analysis with advanced instruments.
3. Developing the capabilities of researchers and staff at the center and transferring technology to gemstone entrepreneurs. To increase the country's competitiveness in both academic and industrial sectors.

Progress/Findings/Results:

This project consists of 4 activities as follows:

1. Procurement and Facility Preparation Activity: The procurement of FTIR-Microscope, Gem Microscope, and Hydrostatic Weighing has been successfully completed. These instruments have been installed and are in use for research purposes. The engineering

systems of the building have been upgraded to accommodate the installation of these instruments. A space has been prepared to facilitate service provision.

2. Database: The researchers have collected 100 samples of rubies and sapphires from various origins including Thailand, Myanmar, Mozambique, Madagascar, and Tanzania. These samples were prepared by slabbing two faces. Subsequently, analytical by basic instruments such as Refractometer, Gem-Microscope, UV-Lamp, etc. Advanced instrumentation, including FTIR, Raman, UV-Vis-NIR, and LA-ICP-MS, was utilized for in-depth analysis. The analytical results are currently being processed to generate a comprehensive database that elucidates the correlations between each origin. Furthermore, experimentation is underway with quality enhancement by ion beam technology, aiming to identify conditions that are optimal for each gemstone origin.

3. International exchange and research: In October, researchers visited the University of Graz and the University of Vienna, Austria to conduct experiments on samples using LA-ICP-MS, Raman, and FTIR instruments, exchanging knowledge in sample analysis techniques using advanced instruments, along with experts. Researchers have applied their knowledge in practical ways, such as in sample holder tools and sample preparation methods. Further activity is to visit the University of Oslo, Norway in January 2024, with the objectives of knowledge exchange on ion beam technology and laboratory management.

4. Public relations and technology transfer: The project has actively promoted its activities to entrepreneurs in Chanthaburi and Chiang Mai provinces. In addition, we organized a seminar and workshop on the “Application of Spectroscopy to Gemstone Enhancement. This event aimed to bring together researchers and entrepreneurs interested in mineralogy, gemstones, advanced instruments, and their applications. Its purpose was to upskill and improve knowledge in the field of mineral and gemstone analysis. The featured speaker was Prof. Dr. Lutz Nasdala from the University of Vienna, Austria.

Conclusion: The center’s capabilities have been upgraded with the installation of an FTIR-Microscope, gemological microscope, and hydrostatic weighing, and are ready to support frontier research. In the process of creating a database, 100 samples of rubies and sapphires have been prepared and collected from Thailand, Myanmar, Mozambique, Madagascar, and Tanzania. These samples are being analyzed to obtain the gemological properties using basic and advanced instruments ready for ion beam experiments. The international travel for research exchange in Austria was conducted in October 2023, involving experimentation with LA-ICP-MS, FTIR, and Raman. The next activity is to travel to Norway in January 2024, with the objectives of knowledge exchange on ion beam technology and laboratory management. The project has actively promoted its activities to entrepreneurs interested in the technology.

Current Output: Publication 1 Topic (Analyzing gemstones using advanced techniques to study gemological properties before enhancement by ion beam technology.) and the researchers and gemstone entrepreneurs utilized the laboratory equipment more than 100 times.

Challenges/Problems and Possible solutions: None

Future Plan: Center of Ion Beam Materials Development and Optical Analysis (CIMO) has been established in Thailand. This center operates as a One Stop Service, providing services for the enhancement of gemstone quality and material science analysis and developing a laboratory for characterizing gemstones, jewelry, and precious metals to meet standards.

Advanced BSL2 laboratory for Vaccine, Probiotics and Feed Functional Ingredient Testing in Controlling Aquatic Animals Diseases

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 30%

Abstract:

Advanced laboratory infrastructure for testing vaccines, bio-supplements, and functional food components to control aquatic animal diseases under a biosafety level 2 system has been established. The design contractor has been engaged, and the design is now complete. The research team has begun designing a cultivation tank system that will incorporate a water quality control system, a temperature control system, and sensors to monitor water quality. They are also in the process of procuring equipment, including a biological safety cabinet, a fermenter, and a superspeed centrifuge. Overall, the project is making progress but is behind the planned schedule.

Rationales/Problem statements:

This project is to develop advanced laboratory infrastructure to test vaccines, bio-supplements, and functional food components to control aquatic animal diseases under a biosafety level 2 system. It is a leading laboratory in the ASEAN region with the ability to replace vaccines and bio-supplements, as well as other high-value compounds with anti-aquatic animal disease properties, to meet the standards for use in the aquatic animal farming industry safely and with maximum efficiency.

Objectives:

Design and construct an advanced laboratory to test vaccines and supplements to control aquatic animal diseases under a biosafety level 2 system. The laboratory will have a one-stop service capability to test vaccines or biological substances that stimulate immunity in aquatic animals to resist pathogens in a comprehensive manner. It will be able to prepare vaccine samples at the appropriate level for testing. It will also be able to prepare samples of aquatic pathogens, including bacteria, fungi, and viruses, for use in tests to induce pathogen infections in aquatic animals.

Progress/Findings/Results:

The preliminary design including laboratory space planning and conceptual drawing has been completed. The design was a collaboration between the research team and the Building Department of the National Science and Technology Development Agency (NSTDA), as the project involves the renovation and extension of the existing laboratory. The conceptual drawing will be used in the discussions with the design contractor and the construction contractor in the next stage. The research team has submitted a construction plan and a plan to procure scientific equipment to the National Center for Genetic Engineering and Biotechnology (BIOTEC), its parent organization, and received approval to proceed with the project.

The research team has applied for approval to hire a designer. Initially, there were problems because the design project budget was not high, and the team also wanted a company with

experience in BSL laboratory design. This made it take longer than expected to find a contractor. The design must be completed before the construction contractor and the construction engineer can be hired. The design contractor has been hired and the design is now complete.

The research team has started designing a cultivation tank system that will have a water quality control system, a temperature control system, and sensors to monitor water quality. They are also in the process of procuring equipment, including a biological safety cabinet, a fermenter, and a superspeed centrifuge.

Conclusion:

The project started on April 1, 2023, and received the first budget installment on June 1, 2023. Before receiving the budget, the working group had already started to prepare the concept for the laboratory construction and the procurement of equipment. The preparation for the improvement of the area and the construction of the laboratory was carried out, with the conceptual design and discussions with the relevant parties, namely the Building and Logistics Department, to prepare for the procurement. After receiving the budget transfer, the project approval was requested and the process of hiring the construction designer has started. In terms of the procurement of the three main equipment items, namely Biological Safety Cabinet, Fermenter, and Superspeed centrifuge, the budget has been transferred and it is currently being purchased. In addition, the research team consulted the Biosafety Committee of the National Center for Genetic Engineering and Biotechnology (BIOTEC) for advice on the design and review of the laboratory design to meet the BSL-2 standard. Overall, the project is progressing but is delayed than the planned schedule.

Current Output:

The structural drawings for the laboratory construction have been completed and are ready for the procurement of a contractor.

Challenges/Problems and Possible solutions:

The problem with hiring a construction contractor is that the process is complex and takes a long time to approve and implement. The procurement of equipment is also a time-consuming process.

Future plan:

The construction of the laboratory and the procurement of equipment will be carried out as proposed in the project proposal.

A Unified Analytical System for Investigating Materials' Thermal Gravimetry, Calorimetry and Chemical Properties; and Off-Gases Analysis in Response to Thermal Stimuli Under Simulated Conditions for Decarbonization Technology

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 60%

Abstract:
This project aims to develop an infrastructure for rapid and comprehensive analysis under simulated conditions of material properties related to bioenergy and carbon capture technologies. Such capabilities will then be used to build a database for those materials.
The one-year project involves developing knowledge for analyzing those materials including 1. Biocoal produced from biomass and 2. Solid adsorbents for capturing CO_2 gas with the eventual goal of advancing BECCS technology. In the past 6 months, biocoal produced from several types of biomasses have been analyzed using ultimate and proximate methods. Similarly, for CO_2 gas capture materials, nine types from three classes of materials have been synthesized and analyzed. The installation of the infrastructure proposed in this project is 75% complete, with the remaining tools set to be installed by December 2023. Preliminary data shows that the data obtained from the proposed measurement is well-correlated with those attained from the standard techniques.

Rationales/Problem statements:
Climate crisis caused by GHG emissions such as CO_2 has been recognized as one of the biggest threats of the 21st century. In response to this issue, Thailand has pledged to achieve carbon neutrality by 2050 and net-zero GHG emissions by 2065. To achieve such goals, bioenergy with carbon capture and storage (BECCS) emerges as a pivotal contender technology. However, substantive advancements are required in improving bioenergy production process, specifically in the conversion of agricultural biomass waste into biocoal and developing solid adsorbents for effective CO_2 capture. To accelerate this research, an infrastructure capable of rapidly and comprehensively measuring important metrics for these materials is needed. Additionally, a database of these materials encompassing crucial metrics is required, yet lacking, to facilitate the selection of biomass sources and adsorbents tailored to specific processes.

Objectives:
To develop an infrastructure and methodology to study the thermochemical properties and reaction mechanisms of biomass and biocoal and to study the CO_2 adsorption properties of solid adsorbents under simulated conditions. Such capabilities will serve as a foundation to build materials' database for biocoal and solid adsorbents for CO_2 capture. Besides, research personnels will be developed to help advance the characterization capabilities.

Progress/Findings/Results:
For biocoal production process, fundamental properties of biomass from agricultural wastes including sugarcane leaves, cassava rhizome, corn stalk and corn leaves were investigated. These biomasses were torrefied under different conditions to investigate their compositions, heating values, solid yields, energy yields and combustion index. These properties will be evaluated to for the biomass feasibility as feedstock for biocoal production.

For CO_2 capture materials, the best adsorbents selected from different classes of materials were synthesized including metal-organic frameworks, zeolites, and modified mesoporous silica. Aside from their outstanding CO_2 uptake capacities, they were selected based on the difference in the CO_2 adsorption mechanism and pore structures which will dictate the productivity and lifetime for practical CO_2 capture devices. These materials were fully characterized using powder X-ray diffraction, infrared spectroscopy, N_2 adsorption isotherm, and CO_2 adsorption isotherm analyses to verify their identities and properties. This information will be used to compare the data obtained from the instrument developed in this project.

With regards to the infrastructure proposed in this project, TG-DTA/DSC, mass spectrometer and mass flow controllers have been purchased and 75% commissioned. The instrument is currently capable of studying gas adsorption and torrefaction processes under simulated gas conditions to rate of mass changes and heat profiles during these processes.

In terms of database, a web application has been built for both biocoal and CO_2 capture materials.

Conclusion: Key properties of biocoal and CO_2 capture materials have been obtained using conventional analytical techniques. Installation of the infrastructure is 75% complete. Preliminary data shows that the data obtained from the proposed measurement is correlated with those attained from the standard techniques.

Current Output: 1 web application for storing database, 2 drafted proposals utilizing the infrastructure from this project

Challenges/Problems and Possible solutions:

None

Future plan:

Preliminary results indicate that, most selected biomass in this study has good potential for biocoal production. Further study on bimass thermal decomposition mechanism could provide useful information for process optimization for biocoal production. For CO_2 adsorbent materials a good correlation between CO_2 adsorption capacities obtained from gas adsorption isotherms and thermal gravimetry obtained from the instrument in this project. Future works will focus on measuring more materials under simulated conditions and obtaining several key metrics that are required for process simulation for capturing CO_2 on a device scale.

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านอุตสาหกรรมแห่งอนาคต (Future Industry – GHG Net Zero)

Development of Hydrogen Fuel Cell-supercapacitor Hybrid System for Clean Energy Storage and Conversion

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Project duration: 1 year, from 1 April 2023 to 31 March 2023
Current progress: 46.5%

Abstract: This project combines several research areas of (i) H_2 and thermal storage materials and systems, (ii) materials for supercapacitors, (iii) hybridization of hydrogen fuel cell (FC)-supercapacitor (SC), and (v) integration of hybridized FC-SC with heating/cooling storage. Our team focuses not only on frontier research but also upscaling and optimization of the obtained energy storage and conversion system to approach practical applications. For the last 6 months, we have generated the research outputs of 4 publications in top 10 % or Q1 journals with JIF=4-7, prototype of room-temperature H_2 storage tank integrated with 200 W FC stack, cooling supply from H_2 storage tank during electrical production of FC, and 8 experienced researchers in the field of renewable energy. Currently, we are dealing with the power converter used for hybridizing FC and SC as well as development of new materials for H_2 and thermal storages and SC.

Rationales/Problem statements: According to the greenhouse gas emission and limitation of fossil fuel, renewable and clean energy resources are significantly of interest. One of the promising choices is hydrogen fuel cell (H_2-FC) due to its high energy efficiency with respect to combustion. Although H_2-FC has high specific energy, its low specific power hinders practical applications. Therefore, hybridization of H_2-FC with another energy storage system with greater specific power, i.e., supercapacitor is proposed to obtain highly efficient energy storage and conversion. Moreover, heating and cooling can be achieved from endo/exothermic reactions of hydrides during de/rehydrogenation of H_2 storage tank. In the present work, hybridized FC-SC is integrated with heating/cooling storage to provide not only electricity but also heating and cooling for the household uses.

Objectives:

1. To develop the hybrid system of hydrogen fuel cell stack (FC)-supercapacitor (SC) based energy storage and conversion with the electrical power of 200 W.
2. To integrate the obtained system from (1) with heating/cooling energy storage (HCS).
3. To investigate the performances based on the electrical and heating/cooling energy production of the integrated FC-SC-HCS system.

Progress/Findings/Results: Two hydrogen storage materials of Li-N-F-H and Mg-Fe-Ni-H have been proposed. Li-N-F-H shows reversible H_2 capacities of 3.0 wt. % within 20 min with superior desorption kinetics to unmodified Li-N-H. De/rehydrogenation rate and reversible capacities of Mg-Fe-Ni-H depend on Ni precursors, which better results is obtained from metallic Ni. For upscaling to H_2 and thermal storages, room-temperature hydride of La-Ni-Ce-H shows good cycling stability under ambient conditions. H_2 storage tank integrated with FC stack (200 W) operates properly at ambient condition. Meanwhile, cooling released from H_2 storage tank during electrical production of FC is achieved. In

computations, it is suggested that adding transition metal catalysts improves hydrogen capacity and ab/desorption kinetics for metal hydride-based and carbon-based hydrogen storage materials. Considering materials for supercapacitor (SC), hierarchical nickel and cobalt sulfides binder-free electrodes with a homogeneous coral-like morphology are prepared by simple method. The obtained electrodes exhibit good electrochemical properties with a maximum areal capacitance of 2.16 F/cm^2 at 10 mA/cm^2. In addition, MOF/carbon nanofiber composites are proposed for SC electrodes. The specific capacitance is as high as 250 F/g at a current density of 0.1 A/g, more than 62% improvement. This is because the enhanced specific surface area after growing MOF nanoparticles on the carbon nanofiber. For hybridized FC-SC system, the power converters have been tested in the laboratory. The output voltages from the power converters can be controlled to be suitable for the interconnection between the FC, SC, and household loads. The dashboard is also designed to monitor the electrical powers of the hybrid FC-SC system and the temperature of the thermal storage.

Conclusion: This project focused on high-impact research and optimization of the energy storage systems for real uses. The hybridized hydrogen FC-SC was proposed for electrical production, while heating and cooling obtained from de/rehydrogenation of hydrogen storage tank was integrated for household uses. The improvement of material properties and upscaling of hydrogen and heating/cooling storages were done. Computations helped rational design of high-performance metal hydrides and carbons for hydrogen storages. For supercapacitor, new methods for material preparation were applied to enhanced specific capacitance of the electrodes. In the case of hybridized FC-SC, the fabricated power converters efficiently provided the AC power from fuel cell.

Current Output:

- 4 international publications in top 10 % or Q1 with JIF=4-7.
- prototype of room-temperature H_2 storage tank integrated with 200 W FC stack.
- cooling supply from H_2 storage tank during electrical production of FC.
- 8 experienced researchers in the field of renewable energy.

Challenges/Problems and Possible solutions: -

Future plan:

- Development of new materials and/or preparation methods for supercapacitor electrodes to obtain better performance.
- Study of temperature and pressure effects on the hydrogen adsorption properties.
- Optimization of the upscaled H_2 and thermal storage systems.
- Integration of the power converters on FC-SC hybrid system operating with HCS.
- Study the performances of the integrated FC-SC-HCS system.

Development of Low-CO_2 Plaster Products for Environmental Sustainability and Efficiency Enhancement of Corrosion Protection in Saline Soil and Coastal Areas

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Project duration: 1 year, from 1/Apr/2023 to 31/Mar/2024

Current progress: 58 %

Abstract:
Cracking of masonry and plastering mortars of clay brick wall was a major problem in the hot climate area. The problem was the worst for the wall made of lightweight blocks. In this research, masonry and plastering mortars made from Portland cement, fly ash, expanded perlite, mortar plasticizer, and sand were tested. The testing program included the determination of water demand, setting time, water retention, compressive strength, splitting tensile strength, density, and elastic modulus. For the masonry mortar, the mixes with high calcium fly ash with or without plasticizer could be used with required properties and reduced cost. The mix of expanded perlite gave water retention over the required 70%. The mix containing fly ash and 0.2% plasticizer gave water retention slightly less than 70%. It was recommended that the mix with expanded perlite should be used for indoor plastering and the mix with fly ash and plasticizer should be used for outdoor plastering.

Rationales/Problem statements:
The buildings in Thailand and the neighboring countries are based on masonry wall with plastering on both sides. Most walls are masonry walls made of traditional burnt clay bricks. With advanced in construction technology, lighter weight mortar blocks containing foam (cellular lightweight concrete block), and autoclaved aerated concrete blocks with better performances in terms of temperature insulation and lighter weight are preferred. The plastering of this lightweight block wall required a special plastering mortar as tradition mortar for traditional wall usually cracks under the high absorption.

For indoor plastering, the plaster usually shows less stress due to less exposure to direct sunlight and wind. To fully utilize this plastering internally, expanded perlite is usually incorporated to improve the acoustic and insulation properties. Fly ash (FA) is a good pozzolanic material and has been used successfully as partial replacement of cement for making plastering mortar.

Objectives:
This research aims to investigate the use of Portland cement-fly ash-perlite-plasticizer blends for use as masonry and plastering mortars. The data should provide a good guideline for masonry and plastering mortars of lightweight wall panel both internal and external exposures.

Progress/Findings/Results:
The results presented in this paper indicates that the mortars containing FA, MP and EP are suitable for use as masonry and plastering work. The incorporation of FA and MP result in a slight reduction of water demand of mortar and hence workability improvement. However, the use of EP results in a drastic increase in water requirement of the mixes. The setting times of mortars were slightly increased with the use of FA and MP and were significantly increased with the use of EP due to the large increase in water content. The water retentions of mortars are increased with the use of FA, MP, and EP. The mixes containing FA and 0.2% MP give the water retention slightly less than the 70% as recommended by the ASTM C91. This mix should be suitable for use as outdoor plastering with the provision of care in moisture and evaporation control.

The mixes with EP give high water retentions in the order of between 78-92% and thus are suitable for use as masonry and plastering mortars. The compressive strength, tensile strength, density and elastic modulus were affected by the incorporation of FA, MP, and EP. The strengths, density and elastic modulus were decreased when the mixes incorporated FA and MP. The mixes with EP with high water retention, low strength, density and elastic modulus should be used in the indoor for improving their acoustic and heating properties.

Conclusion:
The mix with expanded perlite should be used for indoor plastering and the mix with fly ash and plasticizer should be used for outdoor plastering.

Current Output:
1) Sakonwan Hanjitsuwan, Chattarika Phiangphimai, Tanakorn Phoo-ngernkham, Properties of Alkali-Activated/Cement Paste as Coating Material, Proceedings of the 9th World Congress on Mechanical, Chemical, and Material Engineering (MCM'23) Brunel University, London, United Kingdom - August 06-08, 2023

Challenges/Problems and Possible solutions:
-

Future plan:
A minimum of 8 international papers will be submitted to the expected journal as the outputs of this research. The journal with the highest impact factor in the field of construction materials is Construction Building and Materials/Case Studies in Construction Materials/Materials and Structures/Cement and Concrete Composites.

Upcycling of Postconsumer PET Plastics into Metal-Organic Framework Superadsorbent for CO_2 and Pollutant Gas Capture

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 70%

Abstract:
Several plastics, such as PET plastic bottles can undergo simple chemical digestion to yield terephthalic acid monomer that can be combined with metal ions (e.g., from electroplating wastewater) to yield metal-organic-framework (MOF) adsorbent. Certain MOFs have high affinity for carbon dioxide gas and various pollutants such as volatile organic compounds (VOCs). This work investigates the potential of PET plastic waste and metal waste upcycling into MOF adsorbent for CO_2 capture. Preliminary results show that MOFs synthesized from spent PET bottles can have quite a good CO_2 uptake of 1-2 mmol/g at 1 atm, room temperature.

Rationales/Problem statements:
Plastic waste, depleted landfills, along with an increasing CO_2 level is a global issue that needs to be addressed. Thailand is facing problem of increasing plastic wastes, and running out of the landfill space. Constructing waste incinerator will solve the problem of landfill, but will still emit high amount of CO_2 and several pollutants into the atmosphere, and cannot achieve net zero emission and carbon neutrality. The utilization or resource recovery of these metal wastes will help realize the concept of circular economy and to help achieve the net zero emission target.

Objectives:
- To synthesize CO_2 adsorbent from used PET plastics
- To recover metals from industrial wastes to be used in MOF synthesis
- To foster high-caliber researchers in the field of carbon neutrality, net-zero emissions, circular economy

Progress/Findings/Results:
A one-pot PET depolymerization simultaneously with MOF growth was achieved in aqueous media using microwave radiation in 30 mins. The obtained UiO-66 MOF from PET showed superior CO_2 sorption performance (despite lower N_2 sorption) compared to UiO-66 synthesized from pristine terephthalic acid monomer (PET monomer) in traditional DMF media. The reason could be due to the number of defects induced in synthesis using PET plastic, rather than perfect crystalline structure when pristine monomer was employed. This demonstrates that defected MOF, or MOF that is synthesized from a not-so-high purity chemicals could actually have hierarchical porous structure that are good for adsorption applications. The CO_2 uptake was obtained from sample with the PET:Zr 1:1 mole ratios at 30 min reaction time with the CO_2:N_2 selectivity of about 7:1 at room temperature and 1 atm atmospheric pressure. We also tried to synthesize Zn-Fe MOF from Zn-electroplating sludge via nitric acid extraction combining with PET monomer obtained from mechanochemical

PET depolymerization, the results showed quite promising CO_2 uptake of about 1mmol/g, which could be favorably compared to UiO-66 synthesized from pristine zirconium salt of about 2mmol/g.

Conclusion:

Currently, at least two MOFs have been synthesized. UiO-66 MOF was synthesized from PET bottle flake in a rapid one-pot aqueous depolymerization simultaneously with growth of defective UiO-66 MOF that has superior CO_2 sorption performance compared to UiO-66 synthesized typically using pristine monomer in organic solvent. It represents a cleaner, energy efficient synthesis of MOF from used PET bottle. The second MOF was synthesized using sludge from Zn-electroplating factory together with BDC monomer obtained via solvent-less mechanochemical depolymerization of PET bottle flake. The Zn-Fe MOF obtained showed moderate CO_2 uptake capacity of about 1 mmol/g, showing promising potential.

Current Output:

- Upcycling plastic waste: Rapid aqueous depolymerization of PET and simultaneous growth of highly defective UiO-66 metal-organic framework with enhanced CO2 capture via one-pot synthesis. Chemical Engineering Journal, 473 (2023), 14539.
- Synthesis of MOFs from recycled waste PET bottles and spent alkaline batteries. MRS Thailand International Conference 2023.

Challenges/Problems and Possible solutions:

The waste source tends to vary quite a lot from batch to batch.

Future plan:

To investigate the effectiveness of the developed MOFs in capturing other pollutants as well as conversion of the captured CO_2.

Frontier Technology for Direct Conversion of CO_2 from Industry to Metal-Organic Framework

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Project duration: 1 year, from 1 April 2023 to 31 March 2023
Current progress: 60%

Abstract:
Metal-organic frameworks (MOFs) are designed as porous platforms to store CO_2 in both solid state as part of MOF structures and gas phase in the nanopore of MOFs, resulting in high storage capacity of CO_2 from various sources. Several types of new CO_2-derived MOFs and other related porous materials have been developed under this project. The second part emphasizes using MOF materials for CO_2 utilization under low-carbon footprint processes. MOF materials are currently studied for their performances and potentials in various frontier technologies related to the reduction of CO_2 emissions, including the preparation of MOF glass that can be formed into a selective carbon capture membrane, industrial-relevant processes to control capture and release of CO_2 in flue gas, and MOF-based electrocatalysts and photocatalysts for converting CO_2 into energy or value-added chemicals.

Objectives:

1. To develop frontier technology to convert industrial CO_2 into MOFs
2. To develop core technology on MOF materials for CO_2 capture and utilization that is related to the industrial requirements
3. To develop human resources in science and technology to contribute to the country's and worldwide Carbon Net Zero policy

Rationales/Problem statements:
Conversion of CO_2 to MOF materials is a promising approach to reduce CO_2 in the atmosphere by storing CO_2 in solid state and transforming it into value-added porous materials. However, it is difficult to overcome the inertness of CO_2 and convert it to several ligands for MOF synthesis. In general, harsh reaction conditions such as high temperature and high pressure or using precious metal complexes are required to transform CO_2 into organic compounds, including ligands for MOF synthesis. However, it is important to develop facile synthetic methods to convert CO_2 into functional porous materials in large scale under relatively mild conditions to realize the contribution of the CO_2-to-MOF concept in a carbon-neutral society. Moreover, the synthetic methods should be able to extend to synthesize several types of MOF materials with tunable properties.

Progress/Findings/Results:
All research topics carried out under the project are divided into two main scopes to achieve the goals of the project. The first scope focuses on the synthesis of MOFs from CO_2. Several approaches have been initiated to overcome the inertness of CO_2 and convert it to ligands for MOF synthesis under mild conditions. A theoretical calculation has been employed for the

hypothetical construction of carbamate MOFs with high efficiency for CO_2 utilization. Various synthetic and analytical data are subjected to clustering automatic classification to create a structural database. In this database, structural information of MOFs is linked to the synthesis results under various synthetic conditions. The correlation is clarified based on the method of materials informatics. Through these analyses, the controlling factors of the synthesis could be extracted, and more than 20 different types of MOFs could be verified. In addition to carbamate-based MOFs, other types of MOFs, including formate-based MOFs and high-valent MOFs, have been synthesized from CO_2 to explore new MOFs with robust structures and tunable properties. These formate-based MOFs and high-valent MOFs are expected for CO_2 utilization under industrially severe conditions such as high acidic conditions and high moisture content. Moreover, the synthesis of covalent organic frameworks (COFs), which are metal-free open frameworks, from CO_2 has been studied. By employing the preparation of CO_2-derived organic linkers, triazine COFs with high crystallinity have been achieved. The second scope of the project aims to demonstrate the use of MOF materials for CO_2 utilization. The development of MOFs in a glassy state or gel phase has been studied to increase the processability of MOFs, especially for the shaping of gas-selective membranes and monoliths for capturing CO_2 from both industrial pre-combustion and post-combustion processes. Among several catalytic CO_2 conversion reactions, electrochemical and photochemical conversion of CO_2 to value-added products is the main focus of studying CO_2 utilization using MOF materials. Both electrochemical and photochemical CO_2 reduction could be achieved at ambient conditions with less CO_2 emission during the processes compared to those of thermal catalysis reactions. The formation of MOF glasses and further uses as heterogenous catalysts for photochemical CO_2 reduction and biomass conversion are also studied. Promising MOFs developed under the project will be expanded to scale up production by collaborating with the industrial section to realize the contribution of MOFs to the Carbon Net Zero policy.

Conclusion:

This research project synthesized several types of CO_2-derived MOFs and related porous materials, including testing for practical synthetic conditions. The obtained MOFs were experimentally tested for their properties and performances. In addition to the synthesis of new materials, the uses of MOF materials for CO_2 utilization are also studied to explore the contribution of MOFs to the carbon net zero policy. The material with good performance will be synthesized on a large scale as a prototype for further industrial use.

Current Output: 7 publications in Q1 or Tier 1 Journals

1) APL Mater., 2023, 11, 041119. (Impact Factor = 6.635, T1)
2) Inorg. Chem., 2023, 62, 11342. (Impact Factor = 5.436, Q1)
3) Dalton Trans., 2023, 52, 15377. (Impact Factor = 4.569, Q1)
4) Angew. Chem. Int. Ed., 2023, e20312095. (Impact Factor = 16.823, T1)
5) Nat. Syn., 2023, accepted. (Impact Factor = N/A , N/A)
6) Chem. Commun., 2023, accepted (Impact Factor = 6.6065, T1)
7) Adv. Func. Mater., 2023, accepted. (Impact Factor = 19.924, T1)

Challenges/Problems and Possible solutions:

Converting CO_2 to carbamate compound is one of the methods of CO_2 transformation into value-added products, which can contribute to MOF material synthesis. However, there is a limitation that the carbamate group is unstable during the process. To overcome the problem, converting CO_2 into a formate compound can provide more stability and expand the synthesis methods for obtaining MOF materials with desired properties.

Future plan:

In this proposed research, the CO_2-derived MOFs will be applied and modified as promising high-performing materials for gas storage and catalytic conversion of CO_2. The derived MOF materials will be experimentally tested for their performance; in the meantime, the simulation and calculation will also be performed to verify the actual reaction mechanism and their performance.

Frontier Technological Research and Development Plan in Advanced Mechanical Engineering for Electric Vehicles Industries to Achieve Carbon Neutral Society

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 68%

Abstract:

This research project focuses on advancing Electric Vehicles (EVs) technology and related thermal, energy, mechanics, and material engineering. The goal is to enhance the competitiveness of the Thai industrial sector by integrating knowledge in heat management systems, battery technology, charging systems, and advanced materials for lightweight structures. The study involves developing compact and printed circuit heat exchangers for efficient battery heat dissipation, both smart charging management and wireless power transfer technology, and innovative energy management technologies. Additionally, it encompasses advanced engineering materials like high-strength steel, aluminum, alloy metals, composites, Functionally Graded Materials, and lattice structures. These initiatives target carbon emission reduction in the transportation sector, aligning with national energy objectives and promoting sustainability in a carbon-neutral society. The collaborative effort among researchers from diverse technologies and manufacturing processes leads to the development of sustainable and efficient materials and production methods for electric vehicles.

Rationales/Problem statements:

The project seeks to advance Thailand's EV industry by innovating in material technology, energy management, and EV charging infrastructures. These efforts are geared towards enhancing the global competitiveness of Thailand's electric vehicle sector and promoting a carbon-neutral society.

Objectives:

1. To cultivate knowledge and innovation in material technology, material processing technology, and components and structures design for EVs to enhance the competitive edge of Thailand's EV industry in the global market.
2. To develop knowledge and innovation in energy management and heat exchange equipment technology to improve the safety and efficiency of EVs, including reducing CO_2 emissions, thereby leading Thailand towards a carbon-neutral society.
3. To advance the technology for managing energy in EV charging stations, including developing rapid and safe charging technology.
4. To enhance the readiness and competency of engineering personnel in the field of mechanical engineering to support the expansion of the EV industry in Thailand.

Progress/Findings/Results:

The research has made significant developments in advancing thermal engineering technology for EVs, with a particular focus on crucial aspects like heat storage systems and power transfer efficiency. Notable achievements include establishing an optimal surface temperature for effective fire suppression within lithium-ion batteries. Additionally, the investigation into printed circuit heat exchangers for energy management systems has underscored the importance of topology in achieving highly efficient flow channels. The study on heat sinks for lithium-ion batteries has introduced innovative technologies, including the utilization of reverse flow behavior within the Tesla valve, which enhances thermal management. Exploring wireless power transfer using metamaterials has resulted in substantial efficiency improvements. Moreover, gaining insights into the factors influencing battery deterioration will significantly shape for future battery management strategies.

In lightweight structure design, applying advanced engineering design and materials through mathematical models and finite element analysis has yielded notable enhancements in the structural efficiency of components and crash support structures in EVs. Implementing structures with Functionally Graded Thickness and Triply Periodic Minimal Surface architecture has demonstrated a higher energy absorption capacity per unit weight than traditional structures. Furthermore, substituting synthetic fibers with composite materials derived from natural fibers has reduced weight and maintained safety standards for crash accidents. The exploration of alloy production through 3D laser machining has offered valuable insights into predicting micro-level stress phenomena, a crucial aspect in optimizing production processes and material properties. This knowledge will be instrumental in ensuring the superior quality and performance of advanced engineering materials and production methods across a wide range of applications.

Conclusion:

1. The literature related to EV technology has been thoroughly reviewed.
2. Energy management technology and heat exchanger models have been developed to enhance the safety and efficiency of EVs.
3. Advanced lightweight materials have undergone formulation and experimentation through material models.
4. Collaborative investigations have been undertaken involving researchers from diverse disciplines and institutions.

Current Output:

Proposed Output/Outcome/Impact	Summary of the Achievement
• 45 Undergraduate students	• 52 Undergraduate students (100%)
• 15 Graduate students	• 11 Graduate students (73.3%)
• 15 Publications (Tier1/Q1)	• 9 Publications (Q1) (60%)
• 6 Conferences (3 Ntl./3 Int.)	• 8 Conferences (8 Int.) (100%)
• 1 Patent	• 2 Patents (2 Under review) (100%)
• 2 Prototypes	• 2 Prototypes (100%)

Challenges/Problems and Possible solutions:

1. Project approval experiences delays compared to the budget plan, resulting in difficulties in project management, regarding procurement, contracting, and budget disbursement.
2. The project lacks a policy to acquire equipment valued above 500,000 Baht. This hinders the acquisition of modern equipment crucial for technology development research efforts.

Future plan:

The future plan includes designing efficient battery pack configurations and heat management systems. It also involves exploring fuel cell integration for enhanced power production, detailed analysis and design of EV components, and leveraging advanced technology like 3D printing and sustainable materials for components production and testing.

New Technology to Utilize CO_2 Emitted from Industry for Maximining Cassava Yield and Carbon Sequestration

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Project duration: 1 year, from 4 April 2022 to 31 March 2023

Current progress: 30%

Abstract: This project aims to utilize CO_2 released from biofuel combustion of a starch factory to enhance growth and yield of cassava. The project period is one year, and this report provides progresses made during the first six months. During this period, most of the research tasks were focused on; 1) preparation of greenhouses equipped with CO_2 feeding and control systems where 4 different varieties of cassava will be planted. Two levels of CO_2 concentrations will be investigated: ambient (ca. 420 ppm) and 600 ppm (elevated). Two modes of CO_2 feeding will also be compared: gaseous and nanobubbles with water, and 2) preparation of cassava plots ready for testing in the open field under ambient and 600 ppm CO_2 concentrations. It is expected that our understanding of response of cassava to elevated CO_2 levels including physiological and mechanistic aspects will be improved. In addition, potential of yield increase via CO_2 fertilization at farm level will also be evaluated.

Rationales/Problem statements: Solutions to climate change require socioeconomic developments toward net-zero emission. Agro-industry and food sectors contribute significantly to the emission of greenhouse gases. In Thailand, casava plantation and many related downstream industries play the important roles in Thai economy. Throughout the value chains, cassava also contribute to a significant fraction of greenhouse gas emission. We hypothesize that if we could recycle CO_2 from the industry and then utilize it in cassava production, it will significantly help reduce the carbon footprint of the entire value chain. In addition, studies in the past also indicate that cassava is highly responsive to CO_2 concentration, potentially leading to enhanced growth and yield. However, this hypothesis has not yet been tested, especially for Thai native cassava variety. We therefore set up the experiments to investigate the effects of elevated CO_2, emission reduction potentials, and to understand the mechanisms of such responses.

Objectives:

1) To develop a system that can transport CO_2 from a release point to the cassava cultivation plots.
2) To enhance cassava growth and yield through CO_2 fertilization.
3) To evaluate carbon budget in a starch manufacturing plant using recycled CO_2 for cassava cultivation.

Progress/Findings/Results:

The progresses made during the first six months of the project period have been mainly towards fulling the objectives 1 and 2. Firstly we have constructed greenhouses to test CO_2 transport modes and responses of cassava to elevated CO_2 concentrations. These greenhouses are equipped with the cooling unit to cope with temperature overshoot during

the daytime, with gas feeding and monitoring systems. Two modes of CO_2 transport are being tested: gaseous form and aqueous form with nanobubbles. We tested the transport modes because transporting CO_2 with water would be more practical in the farmer's field but we have to prove this first under greenhouse experiment. The mode of transport would also affect CO_2 uptake during photosynthesis and therefore the growth and yields. At present, we have finished the greenhouses and the installation of nanobubbles system and have started feeding gaseous and nanobubbles with CO_2 for cassava cultivation. For the responses of cassava to the levels of CO_2, four variety of cassava (KU50, R72, HN, and PR4) have been grown under two conditions: ambient and 600 ppm levels. Pre-tests including photosynthetic rate, stomata conductance, height and transpiration indicate that there are differences in these variables among varieties. It is therefore interesting to see their responses to elevated CO_2, which is currently under investigation. Secondly, we have also cultivated cassava under field conditions at SMS Corporations in Chaiyaphoom province. We will use CO_2 transport technique based on the results from greenhouse experiment, but likely aqueous form as it is more practical under field conditions (from the user perspective). Here we also will investigate cassava growth under ambient and 600 ppm conditions. It is originally planned that CO_2 fed to the cassava plots would be directly channeled from the factory's stack. However, we have found that the flu gas temperature is too high (200-300°C) and reducing temperature to ambient level is costly. We are now planning to utilize the mixed gases made offline to feed to cassava plot to solve this high temperature issue.

Conclusion: Progresses made during the first six months of the projects involve mainly the preparation of greenhouses equipped with CO_2 transport, feeding and control systems, and the preparation of cassava plots under farm conditions. These made them ready for the next phase of testing the responses of cassava to elevated CO_2 concentrations.

Current Output: No output yet as it is during the initial phase of the project.

Challenges/Problems and Possible solutions: As mentioned above, we have faced the challenges to cool down air temperature of the flu gases to be used in the cassava field. The possible solution would be using the mixed gas resembling the flu gas and feed that directly to the cassava plots.

Future plan: Testing the responses of cassava to elevated CO_2 has just been starting after the system preparation. Future activities will mainly be focused on physiological responses and understanding of the mechanisms under both greenhouse and field conditions, budgeting carbon uptake and emission, publishing the findings, communicating the findings to cassava industry, and establishing the collaborations between research and industry via our partners.

Upscaling of Perovskite Solar Cells for Energy Transition Towards Net Zero

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Project duration: 1 year, from 01 April 2023 to 31 March 2024

Current progress: 85%

Abstract:

Perovskite solar cells (PSCs) have gained attention for their increasing power conversion efficiency (PCE), cost-effective processing, and recent advances in low-temperature synthesis. Achieving efficiencies over 25%, this research focuses on key aspects: 1) developing stable solar cells with eco-friendly materials, 2) scaling up cells to 12 square centimeters, 3) meeting ISOS standards in cell encapsulation, and 4) testing under low light conditions. Key findings include 1) 5x5 cm perovskite layers matching efficiency with larger films, 2) achieving 18% efficiency with needle ablation and metal electrodes in medium cells, and 6.8% in large cells, and 3) demonstrating stability for at least 100 days in metal-electrode solar cells, with ongoing improvements in butyl rubber encapsulation. This report provides a concise overview of advancements in these critical areas.

Rationales/Problem statements:

The new knowledge and advancements in the proposal to upscale PSCs involve preparing films at low temperatures and designing efficient, long-term-use protective coatings using a simple and environmentally friendly process. This addresses the issue of greenhouse gas emissions in production, with perovskite having a lower emission factor (~10 g CO_2-eq/kWh) compared to silicon (~ 55 g CO_2-eq/kWh). The research aims to (1) develop sustainable materials for light absorption and charge transmission, (2) manufacture large-size films to assemble PSCs with over 12 cm^2 of active area, and (3) create a simple and environmentally friendly encapsulation while testing prototype cell stability. The anticipated outcome is PSCs with an area exceeding 12 cm^2, over 10% efficiency under standard conditions, and over 20% efficiency under low light (1000 lux) for more than three months of continuous operation. The project aligns with a sustainable future by addressing persistent problems and potentially evolving towards a low-carbon society.

Objectives:

1. To develop eco-friendly solar materials and processes.
2. To produce a larger-scale prototype (>12 cm^2)
3. To improve cell stability, aligning with ISOS standards
4. To test with small electrical devices under low light conditions (1000 lux).

Progress/Findings/Results:

(1) Sustainable Light-Absorbing Layer: A large-area light-absorbing layer (4x5 cm^2) is crafted using a spin coating technique with antisolvent spray under controlled dry air. This novel approach achieves a noteworthy 14% efficiency, showcasing its potential compared to traditional methods.

(2) Small-Size (S-size) Solar Cells: Solar cells with carbon electrodes are assembled and tested, yielding an impressive 25% efficiency under low light conditions (1000 lux). The addition of an excess of 4 mol% PbI_2 shows promise for further efficiency improvement.
(3) Electrode Design for Medium-Size (M-size) Solar Cells: Critical aspects of electrode design for medium-size solar cells are addressed, including the development of laser-synthesized P1, P2, and P3 lines. Advances in carbon electrode development enable connections between adjacent solar cell electrodes. Transparent conductive glass patterns are designed for assembling medium-size solar cells.
(4) Medium-Size (M-size) Solar Cells: Experimental connections of small-size solar cells result in medium-size configurations with a 6 cm^2 active area. The use of needle etching and metal electrodes replaces laser etching and carbon electrodes, with ongoing development aiming for enhanced efficiency and stability.
(5) Unencapsulated Stability Testing: Durability testing according to ISOS standards is conducted on unencapsulated solar cells. Notably, those with metal electrodes exhibit exceptional stability, enduring for a minimum of 100 days.
(6) Electrode Design for Large-Size (L-size) Solar Cells: Transparent conductive glass patterns are developed to pave the way for large-size solar cells with a 5x5 cm^2 base area.
(7) Large-Size (L-size) Solar Cells: Assembling large-size solar cells using needle etching and metal electrode knowledge results in an active area of 12.16 cm^2 and a power conversion efficiency of 6.80%.
(8) Materials for Solar Cell Encapsulation: The design phase for encapsulation materials involves creating a layout for butyl rubber, including the compression process with medium-size solar cells.
(9-13) Ongoing Encapsulation and Stability Testing:
Continued efforts are dedicated to testing encapsulation and stability for *S-, M-and L-size solar cells* following ISOS standards. These steps are essential for assessing the long-term viability and reliability of the developed solar cell technologies.
This plan advances efficient and stable solar cell technology across sizes, emphasizing ongoing innovation in renewable energy.
Conclusion: This research propels sustainable solar cell technology, excelling in large-area light-absorbing layers, diverse cell sizes, and stability testing. The systematic approach reflects a dedication to enhancing efficiency and stability, vital for renewable energy evolution. Ongoing work emphasizes commitment to innovation in the field.
Current Output: (1) A Novel Carbon Electrode for Up-scaling Flexible Perovskite Solar Cells, *Applied Materials Today*, 34 (2023) 101895 (Q1, IF = 8.663)
(2) Dual Interfacial Tin-Oxide Layer with Chloride Salt for High-Performance and Durable Perovskite Solar Cells, *ACS Applied Energy Materials, 2023 6, 20, 10364* (Q1, IF = 6.959)
Challenges/Problems and Possible solutions: Addressing challenges requires refining coating processes, optimizing electrode connections, exploring encapsulation methods, and adopting a gradual scaling strategy.
Future plan: Enhancing the efficiency and stability of large-scale solar cells (12 cm^2) includes practical testing with small electrical devices under low light conditions (1000 lux).

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The Development of Educational Personnel Competency in the Digital Age to Improve the Quality of Life and Competency of Underprivileged Children in Urban Communities, Chiang Mai Province

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Project duration: 3 year, from 1 November 2021 to 31 October 2024
Current progress: 70%

Abstract:
This study aims to explore categories, quality of life, and underprivileged children competencies, and study guidelines for improving educational personnel competencies in the digital age to elevate the quality of life and underprivileged children competencies in urban communities, Chiang Mai province. Results: The study found that underprivileged children from 6 schools fall into 10 categories, Of the 1,449 underprivileged children (61.45%), Eleven factors affect their life quality, including household income, family occupation, expenses, family size, current residence, ethnic group/stateless status, food adequacy, medical welfare, daily technology use, and school commute. Overall, their basic and core competencies are low.The second-year study on digital-era educational personnel development for improving underprivileged children's lives and skills in urban communities involves 162 school administrators and teachers. Projects align with the specific needs and problems of each school's personnel to enhance children's quality of life and skills. Six schools have 12 projects in the 2023 Action Plan

Rationales/Problem statements:

Underprivileged children living in urban communities, often migrants following parents, both stateless and Thai, reside in the city or labor camps without household registration, living densely. They work as laborers, including construction, housekeeping, gardening, cleaning, etc. Types of underprivileged children include the extremely poor, drug-related issues, abandoned, abused, ethnic minorities, homeless, and child labor victims. Therefore, support and care for these children rely on developing educational personnel, like school administrators and teachers, with specific competencies, using schools as development bases with diverse activities, both onsite and online, through digital communication channels. Tailored to each type of underprivileged child's context, the expected outcome will elevate their life quality and competencies, improve life opportunities, and reduce educational disparities in this era of change.

Objectives:

To study the quality of life and competencies of underprivileged children in urban communities of Chiang Mai Province.
To research approaches for developing the competencies of educational personnel in the digital age to enhance the quality of life and competencies of underprivileged children in urban communities of Chiang Mai Province.

Progress/Findings/Results:

Exploring categories, quality of life, and underprivileged children's competencies was conducted through in-depth interviews and public hearings with 180 school administrators, teachers, representatives of underprivileged children's parents, and experts obtained by Purposive Sampling. Studying guidelines for improving educational personnel competencies was conducted through competency assessment and workshops with 162 school administrators, teachers, supervisors, and experts, selected through Purposive Sampling

The study found that underprivileged children from 6 schools fall into 10 categories, including 1) extreme poverty, 2) drug issues, 3) abandonment, 4) abuse, 5) affected by AIDS or severe contagious diseases, 6) ethnic minorities/stateless groups, 7) children of laborers, 8) forced labor, 9) involved in the sex trade, and 10) special needs. Of the 1,449 underprivileged children (61.45%), Wat Suan Dok School has 398 (91.92%), Ban Phra Non School 135 (72.19%), Ban Pa Tan School 169 (64.75%), Community School at Wat Tha Duea 147 (58.10%), Municipal School at Wat Sri Don Chai 247 (54.14%), and Ban Mae Jo School 353 (45.84%). Eleven factors affect their life quality, including household income, family occupation, expenses, family size, current residence, ethnic group/stateless status, food adequacy, medical welfare, daily technology use, and school commute. Overall, their basic and core competencies are low. The second-year study on digital-era educational personnel development for improving underprivileged children's lives and skills in urban communities involves 162 school administrators and teachers. Projects align with the specific needs and problems of each school's personnel to enhance children's quality of life and skills. Six schools have 12 projects in the 2023 Action Plan, like the "Sufficiency Learning Ecosystem 'Phra Non' Project" at Ban Phra Non School, Chiang Mai.

Conclusion:

The new paradigm for educational personnel development in the digital age focuses on elevating the life quality and skills of underprivileged urban children. Despite living in cities, these children often face neglect. The approach aims to ensure they are not left behind, promoting lifelong learning and readiness for the digital future. Educators are pivotal in this transformative process, enhancing their digital, communication, and health knowledge competencies to effectively address each child's unique needs, fostering their growth as societal and global citizens.

Current Output:

The second year of the project for the development of educational personnel in the digital era to enhance the quality of life and capabilities of underprivileged children in urban communities has created a new model for developing educational staff. This model is characterized by its specificity and alignment with the problem conditions in each school. It is a collaborative effort involving all stakeholders, including academics, experts, school administrators, and teachers, incorporated into the 2023 (Action Plan) of all 6 schools, with a total of 12 projects. This initiative facilitates systematic and continuous development, representing an innovative approach to educational staff development, with schools serving as the foundation, enabling appropriate application for school administrators and teachers.

Challenges/Problems and Possible solutions:

Innovative development for educational personnel aims to enhance knowledge, understanding, and competencies in practice, learning management, and health. These will be used as tools to promote life and vocational skills, as well as health for underprivileged children in their schools. This approach intends to create equity and educational opportunities, ensuring underprivileged children can develop to their full potential.

Future plan:

The development and scaling of innovation for the advancement of educational personnel arise from collaborative design and execution by experts from various disciplines and organizations. This is directed towards schools in different areas to serve as a model for educational staff development at the school level, classroom level, and individual level among underprivileged urban communities. The goal is to improve the quality of life, enable honest self-sustenance through employment, and foster good societal membership.

Smart Learning Platform for Learners' Competencies Development in the Digital Environment: Science Subject

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 65%

Abstract:

This study introduces the Web-Enhanced Inquiry Learning for Literacy in Science (WILL-S), a novel online learning platform developed to augment literacy in science among secondary school students. WILL-S, underpinned by a pedagogy-driven approach, encompasses four distinct versions tailored to various pedagogical applications. The platform's efficacy was evaluated through its implementation with 170 students across eight schools in four Thai provinces. A rigorous stepwise multiple regression analysis was employed to test hypotheses about the platform's impact on student's academic performance in science literacy. The findings reveal a significant contribution of the WILL-S platform, accounting for 40.70% of the variance in enhancing academic performance in science literacy. This study not only underscores the potential of web-enhanced inquiry learning in secondary education but also provides insights into the effective integration of technology in science education, particularly in diverse educational contexts like Thailand.

Rationales/Problem statements:

This research addresses the critical need for innovative educational strategies to enhance literacy in science among secondary school students. Despite the growing emphasis on STEM education, a significant gap persists in effectively integrating literacy skills within science curricula. Traditional instructional methods often fail to engage students actively and meaningfully in the scientific inquiry process. Additionally, the rapid advancement of technology in education presents both a challenge and an opportunity to revolutionize teaching and learning practices. The lack of pedagogy-driven, technology-enhanced learning platforms that cater to diverse learning styles and needs further exacerbates this issue. This gap is particularly pronounced in varied educational settings like Thailand, where resources and teaching approaches may differ significantly across regions. Hence, this study introduces the Web-Enhanced Inquiry Learning for Literacy in Science (WILL-S) platform, aiming to bridge these gaps by offering a versatile, inquiry-based online learning environment that aligns with contemporary pedagogical approaches to enhance science literacy.

Objectives:

The primary objectives of this research are to: 1) Develop and implement the Web-Enhanced Inquiry Learning for Literacy in Science (WILL-S) platform, a pedagogy-driven online learning tool designed to improve science literacy among secondary school students. 2) Investigate the effectiveness of WILL-S in enhancing students' academic performance in science literacy across diverse educational settings in Thailand. 3) Examine the impact of different pedagogical applications integrated within the four versions of the WILL-S platform.

Progress/Findings/Results:

Research Progress:
The research commenced with developing the Web-Enhanced Inquiry Learning for Literacy in Science (WILL-S) platform, a comprehensive online learning tool designed for secondary school students. The development phase involved creating a pedagogically sound structure that integrated various teaching methodologies tailored to different learning styles. The platform was segmented into four versions, each embodying a unique pedagogical approach, ranging from guided inquiry to problem-based learning, to ensure a diverse and enriching learning experience. The implementation phase saw the WILL-S platform being introduced across eight secondary schools in four Thai provinces, encompassing a broad spectrum of educational settings and student demographics. This phase was critical in evaluating the platform's adaptability and effectiveness in real-world classroom environments. Special attention was paid to the seamless integration of WILL-S into existing curricula, ensuring that the platform complemented traditional teaching methods while providing an innovative approach to science literacy. The implementation involved 170 students, providing a substantial sample size for robust data collection and analysis. Throughout the research, continuous feedback was gathered from both students and educators. This iterative process allowed for the refinement of the platform, ensuring that it remained responsive to the needs of its users and effective in its educational aims. The progress of the research highlighted the complex nature of integrating technology in education, especially in varied settings, and underscored the importance of a flexible, user-centric approach to educational technology development.

Results:
The research yielded substantial data regarding the effectiveness of the WILL-S platform in enhancing science literacy among secondary school students. The results were derived from a combination of qualitative feedback and quantitative performance metrics. The quantitative data primarily focused on academic performance in science literacy, comparing baseline assessments with post-implementation results. A notable observation was the variation in effectiveness across the four versions of the WILL-S platform. Each version, with its unique pedagogical approach, resonated differently across various schools, highlighting the importance of context in educational technology implementation. Moreover, student engagement levels varied with different versions, suggesting a correlation between the pedagogical approach and student interest and motivation. Qualitatively, feedback from students and teachers indicated a generally positive response towards the platform. Teachers noted an increased interest in science subjects and a more profound engagement with the learning material. Students reported enjoying the interactive and inquiry-based nature of the platform, which made learning more relatable and less abstract.

Findings:
The findings of the research were multifaceted, shedding light on the impact of web-enhanced inquiry learning on science literacy. The most significant finding was that the WILL-S platform accounted for a 40.70% increase in the variance in academic performance in science literacy among the students. This statistic was a robust indicator of the platform's effectiveness in enhancing students' understanding and proficiency in science. Another key finding was the differential impact of the various pedagogical approaches within the WILL-S platform. The data suggested that no single approach was universally effective; instead, the effectiveness varied according to the specific educational context and student demographics. This finding underscores the need for flexible and adaptable educational tools catering to a diverse student population. The research also highlighted the critical role of teacher involvement and support in successfully implementing educational technology. Teacher feedback suggested that the integration of WILL-S into the curriculum was more

effective when teachers were actively involved in the process, using the platform as a complementary tool to traditional teaching methods.

In conclusion, the research provided valuable insights into the potential of web-enhanced inquiry learning platforms like WILL-S in enhancing science literacy. It also highlighted the complexities and nuances of integrating technology into education, emphasizing the need for adaptable, context-sensitive solutions.

Conclusion:

The conclusion of this research underscores the significant impact of the Web-Enhanced Inquiry Learning for Literacy in Science (WILL-S) platform in enhancing science literacy among secondary students in Thailand. The study demonstrated a substantial increase in academic performance, with WILL-S contributing 40.70% of the variance in student achievement. The effectiveness of different pedagogical approaches within WILL-S varied across diverse educational contexts, highlighting the importance of adaptability and context-specific application in educational technology. Furthermore, the research emphasized the crucial role of teacher involvement in successfully integrating such technology, suggesting a collaborative approach in educational innovation.

Current Output:

Publication:

Scopus-indexed conference proceedings:

1) Srisawasdi, N., Chaipidech, P., Pondee, P., Chaipah, K., Panjaburee, P., Khaokhajorn, W., Premthaisong, S., & Tuamsuk, K. (2023). Designing and implementation of web-enhanced inquiry learning for literacy in science platform for post COVID-19 education. In T.-H. Meen (Ed.), 2023 IEEE 6th Eurasian Conference on Educational Innovation (ECEI) (pp. 111-114). Singapore University of Social Sciences, Singapore. https://doi.org/10.1109/ECEI57668.2023.10105362
2) Muangbangyung S, & Srisawasdi N. (2023). Design and development of interactive Moodle-based e-learning platform for competency training. *Engineering Proceedings*, 38(1), 11. https://doi.org/10.3390/engproc2023038011

Journal article:

1) Muangbangyung, S., Srisawasdi, N., Chaipidech, P., Premthaisong, S., Panjaburee, P., Pondee, P., Chaipah, K., Khaokhajorn, W., & Tuamsuk, K. (202x). Investigating the influence of technology, content, and pedagogy affordances on students' intention and literacy in science through a web-enhanced inquiry system. Journal of Science Education and Technology. (submitted)

Prototype: The Web-Enhanced Inquiry Learning for Literacy in Science (WILL-S) – an online learning platform for learners' scientific competencies development

Challenges/Problems and Possible solutions:

One of the primary challenges encountered in this research was the varying effectiveness of the WILL-S platform across different educational contexts. The diverse pedagogical needs and varying infrastructural capabilities of schools in different Thai provinces posed a challenge in standardizing the platform's impact. To address this, future iterations of WILL-S will focus on enhancing adaptability and user customization, allowing for a more tailored approach to cater to individual school and student needs. Additionally, ongoing teacher training and support are crucial in ensuring effective implementation. The integration of learning analytics will also aid in identifying specific areas of improvement, facilitating a more data-driven approach to refine the platform.

Future plan:

Building on the success of the WILL-S platform, the future plans include the focused implementation of the WILL-S (C plus) version, which has shown promising results in initial

trials. This targeted deployment aims to explore further and refine this version's unique pedagogical features to maximize its impact on scientific explanation and inquiry competencies. Additionally, a comprehensive analysis of learning analytics will be conducted using the data log files generated by the WILL-S platform. This analysis will provide deeper insights into student learning behaviors, engagement patterns, and areas for improvement. By leveraging this data, the goal is to enhance the customization and effectiveness of the WILL-S platform, tailoring it more precisely to student needs and learning styles.

Modern Picture Books and Social Expectation of Thai Children in the 21st Century

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Project duration: 2 years and 3 month, 1 November 2021 to 31 January 2024
Current progress: 90%

Abstract:

Modern picture books are expected by Thai society as a medium for moral development, ethics, and healthy habits. ideal Thai youth as well as the consciousness of being Thai There may be a review to see if it has achieved the goal in the past or not. Or, in fact, the use of visual tales in teaching is the wrong setting. Because for children, the important function of fairy tales is to provide fun and enjoyment. and give children the opportunity to interpret It's not a presentation of a ready-made reality series. As Thai visual tales often present like that. The results of this study may lead to suggestions for creating modern visual tales in line with learning in the 21st century.

Rationales/Problem statements:

In Thai society, a “picture book” is a book with descriptions and pictures. and is often referred to as a "tale" book, which gives the meaning that it is a modern picture storybook for children that may be classified by age group. Available in general bookstores with a dedicated corner.

There will be a proportion of the image than the text. That is, the picture is about 70-80% of the page. Double – page, full-page drawing or single-page storytelling. The most important thing is Images are more important than words in conveying a story. The normal number of pages is approximately 32. A picture book must contain picture on every page, whether single or double.

A good picture book must communicate well with children. Some pictures that tell a story. Sometimes there may not be any need for text or to read the characters. Children can read the story and understand the story from the pictures. In addition to this, there is also a very detailed the picture must provide information to the child. The picture must convey the emotion of the character of the story, such as the story's story telling of excitement, mystery, and adventure.

Objectives:

1. To analyze the story and storytelling in Thai modern picture books
2. To analyze the expectations of Thai society towards Thai children appearing in modern picture books

Progress/Findings/Results:

From the research study of basic information about modern picture storybooks. It is enough to see the characteristics of modern Thai picture books and the direction of Thai picture books in the future. Both consistent and inconsistent with the direction of modern international visual storybooks.

Modern Thai picture books are used as a media for moral development, ethics, and healthy habits to look like an ideal Thai child, It's a complete set of ideas. Do not allow the opportunity to interpret and analyze on their own. The most importantly, inconsistent with human development in the 21st century.

If modern picture storybooks are expected by Thai society as a medium for moral development, ethics, and healthy habits. ideal Thai youth as well as the consciousness of being Thai There may be a review to see if it has achieved the goal in the past or not. Or, in fact, the use of visual tales in teaching is the wrong setting. Because for children, the important function of fairy tales is to provide fun and enjoyment. and give children the opportunity to interpret It's not a presentation of a ready-made reality series. As Thai visual tales often present like that. The results of this study may lead to suggestions for creating modern visual tales in line with learning in the 21st century.

Challenges/Problems and Possible solutions:

During the study period, there were many picture books. Each publishing house has its own characteristics. It affects the time taken for collection, analysis, and project execution time.

Future plan:

When this project is finished. There is a need to propose this as a policy for producing Thai picture books in the future in line with the characteristics of children in the 21st century.

Surveying the Knowledge Landscapes of the Humanities in Thailand

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Project duration: 2 years, from 1 August 2022 to 31 July 2024
Current progress: 65%

Abstract:
This study conducts an exploratory survey of the knowledge landscape of the humanities in Thailand to examine the breadth and depth of scholarly work across various disciplines. It involves 31 researchers from diverse institutions in 3 academic branches: 1. Western Languages and Literature (English, French, German, Spanish), 2. Eastern Languages and Literature (Chinese, Japanese, Pali-Sanskrit), and 3. Other branches of the Humanities (Linguistics, History, Philosophy, Dramatic Arts, Library and Information Science), totaling 12 disciplines. The survey examines works published in Thailand from 2013-2022 across all disciplines, as indexed in the Thai-Journal Citation Index (TCI), despite varying historical contexts per discipline. A total of 7,657 research works were found, and a public database of these findings is planned for early 2024. The project's final phase will synthesize these data to assess trends and research dynamics in of humanities in Thailand, comparing them with international standards to identify distinct strengths and weaknesses.

Rationales/Problem statements:
Humanities, a discipline focused on studying humans and their creations, though closely related to humanity, is not always of interest or understood by everyone due to its complexity and continuous subdivision. To enhance the application of humanities studies in addressing human needs and to broaden their accessibility to new scholars, it is crucial to explore the knowledge landscapes of the humanities in Thailand. This survey will help current and future humanities scholars recognize the state of knowledge in their fields, ponder its development, and how it connects with international knowledge. This understanding will propel the development of humanities in Thailand.

Objectives:
1. Survey the knowledge landscape of the humanities in Thailand, focusing on research published locally.
2. Develop an open-access, user-friendly database containing the data from the above survey.
3. Synthesize and analyze the data to uncover interdisciplinary connections and relationships, and to chart potential development directions for the humanities in Thailand.
4. Explore frontier research opportunities by analyzing and comparing the strengths and weaknesses of Thai research against international publications.

Progress/Findings/Results:
The project has successfully achieved objectives 1 and 2, with the database and website scheduled to become publicly accessible around January 2024. Currently, the team working on synthesizing data from the database to explore connections within the knowledge landscape. This process has involved three brainstorming sessions to date. A significant meeting is also planned for December 25, aimed at gathering expert opinions and additional insights.

Conclusion:
The initial year of surveying Thailand's humanities knowledge landscape, focusing on research published within the country, has resulted in the creation of an open-access database covering 12 disciplines, featuring 7,657 works. Notably, there has been a steady rise in Thai research, particularly from 2018 onwards, with a marked growth in applied sciences. The fluctuations in research volume, both increases and decreases, are primarily attributed to social factors such as the availability of research funding, the range of graduate programs offered, and the level of faculty expertise.

Current Output:

1. An open-access database featuring research publications in Thailand.
2. A user-friendly website designed for easy navigation and search of the database contents.

Challenges/Problems and Possible solutions:
The inherent diversity and complexity within the field of humanities present challenges in efficiently synthesizing research findings. To address this, a significant meeting is planned for late December. This session aims to facilitate in-depth discussions and brainstorming sessions, as well as to collect qualitative insights from experts. These efforts will complement and enhance the existing quantitative analysis of the data.

Future plan:
Following discussions with experts and the completion of the analysis and synthesis of Thailand's humanities landscape, the project’s concluding six months will focus on a comparative study. This phase will involve evaluating the strengths and weaknesses of each discipline within the context of global research trends. The aim is to not only benchmark Thai humanities against international standards but also to identify unique areas of development and potential. This comprehensive approach ensures a holistic understanding of the field's current state and future possibilities, paving the way for informed advancements in both academic and practical applications of humanities in Thailand.

Wat Phra Rup Museum Development Project as a Learning Center and Creative Economy

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Project duration: 1 year, 1 August 2022 to 31 July 2023 (Extended 6 Mount)
Current progress: 75%

Abstract:

This research uses the concept of creative economy as its foundation and then tops up the success of the research and development project in order to upgrade Wat Phra Rup Museum in Suphan Buri province to become a lifelong learning resource. The results of topping up the body of knowledge in the Museum are shown in three following characteristics: (1) the creation of self-conscious of realization in local history and conservation of traditions and culture of the temple; (2) the creation of souvenir products from the identity of art objects in the Museum; and (3) the development of products in collaboration with entrepreneurs in the community who have products that have passed the distinction analysis, which shows the mutual support and promotion between the learning resources in Wat Phra Rup Museum and the products related to the Museum leading to the development of Wat Phra Rup Museum to become a new center in being a sustainable learning resource and having a part in mobilization of grass root economy.

Rationales/Problem statements:

In continuation from the results of research and development to upgrade Wat Phra Rup Museum in Suphan Buri province to become a lifelong learning resource that is appropriate for Thai society in the 21st Century by this group of researchers, it is found that Wat Phra Rup Museum is not only a lifelong learning resource, but can also be developed to top it up as a museum in the dimension of creative economy that is important for mobilization of grass root economy. This is because Wat Phra Rup not only has Wat Phra Rup Museum; it also has within its area a large number of archeological sites that can serve as tourist attractions. Moreover, the areas surrounding Wat Phra Rup have physical components that have the potential to attract tourists, and the communities surrounding Wat Phra Rup also have local wisdom products that are outstanding. All of these are factors that support Wat Phra Rup Museum to be a new center of learning resource and creative economy.

Objectives: This research has the objective to develop Wat Phra Rup Museum to become a new center of learning resource and creative economy by conducting a study to top up the body of knowledge appearing in Wat Phra Rup Museum.

Progress/Findings/Results:

There are three main activities in the research operation. The research results during the recent period have achieved the specified goals as follows: 1) Regarding “activity to restore the annual festival to worship the Lord Buddha’s Footprint at Wat Phra Rup”, the researchers had taken field activities in the area to collect in-depth information concerning the history of the wooden Lord Buddha’s Footprint and the annual festival to worship the wooden Lord Buddha’s Footprint at the temple in the past. After that, they took the information to be analyzed and synthesized in order to create the body of knowledge showing the importance of the wooden Lord Buddha’s Footprint as perceived by the people in the temple and community since the past until the present time. The obtained body of knowledge had been written as a book for dissemination in order to create the self-conscious of realization in the local history and the continuation of the traditions and culture of the temple. In addition, the

researchers also gave advices to the temple people and the community in construction of a pavilion and production of imitated wooden Lord Buddha' Footprint. They also collaborated in restoring the annual festival to worship the Lord Buddha's Footprint at Wat Phra Rup to be renewed as the same festival as in the past, with the transforming of the festival days to be appropriate for the present condition of the temple and the community. 2) Regarding "activity to design the souvenir products in the Museum", the researchers had synthesized the body of knowledge from the Museum to be applied for designing to create the souvenir products of the Museum. As a result, "the wooden Lord Buddha's Footprint" that is the most outstanding or the most excellent ancient object of the Museum had been selected to be applied for making decorative designs on four created products, namely, the imitated wooden Lord Buddha's Footprint for worship, the cloth bag, the key bunch, and the coffee cup case. All product prototypes had been created on time as planned. 3) Regarding "activity of designing salted egg container of Wat Phra Rup", the researchers had taken field activities in the area to search for the identity of outstanding wisdom of Wat Phra Rup community. They had selected "Mae Fuen's salted egg" that is the famous salted egg of Suphan Buri. They also collected in-depth information from entrepreneurs including the historical background and the steps of making salted egg. In addition, they had also designed the development of added value of the salted egg in terms of bamboo wickerwork container prototype which was inspired by ancient objects in the Museum. In addition, they had also designed an information label for the container which was inspired by Phra Malai Picture Book and the shape of Khun Phaen Printed Buddha Image. The provision of knowledge on making various salted egg menus that appears on the label helped to create the perception connecting with the learning resources of Wat Phra Rup Museum and mobilize the salted egg of Wat Phra Rup community to become a little present in various merit festivals of the temple. Furthermore, the results of this activity had been developed as an academic article. In the operation of designing all products from Wat Phra Rup Museum, all involving parties had collaborated including the abbot of Wat Phra Rup, entrepreneurs and community leaders, experts on designing products, and the group of researchers. This is an experiment in the development of the products with unique identity and the creation of added value, which arises from the needs of local people who are the true owners of the culture. The products are appropriate and sustainable, and also appropriate for the marketing.

Conclusion:

The top up development of Wat Phra Rup Museum to become a new center of learning resources and creative economy via the operation of three activities of the project by creating various prototype products and creating academic works in terms of books and academic articles based on the academic principles, the collaboration and the true needs of the temple and the community is the upgrading of the temple museum work to another higher level and is the prototype for development of other temple museum works and other communities in the future.

Current Output: There are four types of prototype products, namely, wooden Lord Buddha's Footprint for worship, cloth bag, key bunch, and coffee glass case.

Challenges/Problems and Possible solutions: -

Future plan:

After finishing the creation of products of the project, the future plans are as follows: 1) There is a plan to expand the results of producing souvenir products of Wat Phra Rup Museum and mobilize the temple and the community to open the community shop of the Museum, which at present the temple has already prepared the place for the shop. 2) There is a plan to promote the salted egg product of Wat Phra Rup community to be a little present for distribution in merit festivals and cremation work of Wat Phra Rup and other temples in Suphan Buri province.

A Study of Public Recreational Place for Quality of Life and Well-being of Disabled People

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Project duration: 2 years, from 1 November 2021 to 31 October 2023 (Extended to 30 April 2024)
Current progress: 83.50%

Abstract:
Public parks are a community resource with an important role in improving liveability, physical, and mental wellbeing. However, exercise facilities that are suitable for people with disabilities typically have been neglected in public park design. As such, people with disabilities often are unable to independently or safely use the park. To address this shortcoming, the objective of this paper was to employ a pragmatic research through designing process in developing the design for an inclusive park. We used a mixed-methods approach in the research that included review of previous studies, semi-structured interviews, and questionnaire surveys with stakeholders were applied as design integration. Persons with disabilities specifically were consulted to express their views on all matters of inclusive park design.

Rationales/Problem statements:
The number of disabled people in a given context is often underappreciated and underestimated. The World Health Organization reported that over 15% of the world population is affected by disabilities (WHO, 2011). In the reality, the population size of those living with disabilities can be considered even larger given the chance of contracting a disability during the path of life (WHO, 2022a), as well as the wide range of the disabilities (ibid.). The difficulty in accurately estimating the number of people living with disability is that impacts extend beyond the traditional health sciences and include those connected to the personal and social isolation of the affected individuals (Emerson et al., 2021), and also is linked to issues of loneliness (Gómez-Zúñiga et al, 2023).
This study follows the definition of the principles for inclusive and accessible parks in Pathum Thani Province, Thailand (Selanon et al., 2022a), and the selection of a green existent area (The Thammasat Water Sport Center) within this provincial context where a possible redevelopment into an inclusive and accessible park for disabled is expected to have potential success (Selanon et al., 2022b). The objective of the research presented herein is to redevelop the existing space into an inclusive park for autonomous access by the disabled community.

Objectives:
1) To study the physical needs of exercise areas and rest areas of people with disabilities in various fields.
2) To study guidelines for designing exercise areas and rest areas in public parks that are safe and suitable for the needs of people with various disabilities.
3) To develop a prototype of an exercise area. and resting areas in parks that are safe for people with disabilities of all physical abilities to improve the quality of life and promote the fitness and good health of people with disabilities.
4) To find ways to create cooperation between the private sector and the government sector in adopting the concept of the design into concrete practice.

Progress/Findings/Results:

Researchers have developed alternative solutions for public rest areas to improve the quality of life and health of people with disabilities. Abandoned, based on civilized architecture or design and development standards designed for everyone. Therefore, in terms of space utilization and material selection, there are safety precautions in place for valuation. (BOQ) The construction cost is relatively high, so gradually seeking support from various departments. Thammasat University Property and Sports Management Office The construction plan should be adjusted to reduce construction costs. The construction will be divided into two parts, the first part. It will be infrastructure construction and system work, such as demolition work, bridge pier and pile driving work, flooring work, and various system work. Part 2. Construction will begin in February 2024.

In terms of article publication, the researchers published three articles to showcase the research results. Article 1: Walking activity increases physical abilities and subjective health in people with seven different types of disabilities, which is published in the journal, "Frontiers of Public Health" in Scopus Q1 database. Article 2 is titled, "The Importance of Urban Green Spaces in Enhancing Holistic Health and Sustainable Well-Being for People with Disabilities: A Narrative Review, which is published in Buildings in Scopus Q1 database. And the 3rd article is "Residential Interior Design for People with Special Needs in Thailand Based on Physical Abilities: Age, Gender, and Living Environment Considerations," which is also published in the Buildings in Scopus Q1 database.

Conclusion:

During the project's implementation period of months 19 - 24, there was a delay in the research process due to the process of finding a financial support for constructing the park. However, the project completed implementation of 3 objectives, which help create benefits and positive impacts on society at large, including:

1) Results of the study of the physical needs of the exercise area. and resting areas for people with disabilities in various areas that bring information about behavior patterns and the potential and limitations of people with disabilities.

2) Guidelines for designing exercise areas and safe and appropriate rest areas in public parks, which helps develop academic knowledge and standards in designing for people with disabilities for various agencies, public parks, and educational institutions that teach landscape architecture

3) Results of prototype development of the exercise area and rest areas in parks that are safe for people with disabilities that helps lead to a society with equality. In addition, disabled people will have a better quality of life and better physical and mental health. see self-worth and able to use one's potential to its fullest potential. These disabled people will be able to live together with normal people equally and equally.

The next action plan is to build the park and organize a public hearing activity. After that the study will analyze result from the public hearing to compile guidelines for creating cooperation to create plans and actions. Operations will be carried out according to objective number 4 in creating guidelines for cooperation between the private and public sectors. There will be discussions together to disseminate and develop knowledge.

Current Output:

New knowledge new criteria and suggestions for designing exercise areas (Active Recreational Space) and relaxation areas (Passive Recreational Space) in public parks that are consistent with the needs of people with disabilities and their physical characteristics,

and that people with disabilities can use them efficiently. 1 piece safe, 80% progress
2) Prototype for designing exercise and relaxation areas that were actually built in a former park in Bangkok that was consistent with the physical characteristics and needs of people with disabilities, 1 piece, 80% progress.
3) Research articles published in 3 academic journals, 100% progress.
1) Creating cooperation between the private and public sectors in bringing design ideas into concrete practice. Progress 70%.

Challenges/Problems and Possible solutions:

Obstacles

- Requesting permission to request financial support for construction is delayed. Because there is an overlap between fiscal year 2023 and fiscal year 2024
- the process for selecting journals to publish articles is difficult. This is because the issues that need to be published and the Impact Factor are not consistent with the needs.

Solutions

- Letters requesting assistance requesting financial support for construction have been sent to many companies so that the actual construction work can be carried out as quickly as possible.
- The researchers decide to submit to the journal that is most relevant to the content of the study. Subsequently, the researchers propose to the PMU-B to adjust the details of the journal used for publication.

Suggestions

Requesting permission to request financial support for construction should be carried out from the beginning of the project because it is a process that takes a long time to contact and present to the private sector.

Future plan:

This prototype model can be promoted as an academic and professional study area for students, professors, researchers, architects or designers. and everyone who is interested in designing the use of public spaces for people with disabilities that is comprehensive and responsive to use by all people and all ages (Inclusive and Universal Design). A society with equality and sustainability (Equity and Sustainability). Observations will be made to collect data on the behavior of users of the area. Advantages and limitations Including additional needs for continued use of the area for academic and professional benefits.

"Balanced Multiculturalism": Building Intercultural Competence for Multicultural Co-existence with Migrant Workers from Myanmar, Cambodia and Lao in Thailand

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 91.66%

Abstract:
The second year of the study is aimed to investigate the coexistence situation between the local Thais and migrant workers in Thai society, which exposes both positive and negative aspects of social relations and attitudes toward each other. The survey on coexistence was conducted with 1,060 Thai individuals and 1,016 migrant workers from Myanmar, Cambodia, and Laos in Bangkok, Pathum Thani, Samut Prakan, and Samut Sakhon, together with Observation and in-depth interviews. The findings show that under the frame of coexistence in terms of acceptance, respect and appreciation, overall, Thai participants and migrant workers expressed neutral attitude and exhibited passive tolerance. That was based on the extent of understanding and respecting the rights of others, even if they are somewhat contrary to one's thoughts or feelings, to avoid conflict and maintain peace and order in living together.

Rationales/Problem statements:
In a globalized era where travel and mobility are easily accessible together with economic development, the change in population structure towards an aging society has exacerbated international migration. Currently, numerous nations are identified as multi-ethnic communities as a result of increased migration. The coexistence of immigrants, regardless of their permanence or temporary status, inevitably involves clashes of cultural differences and can have both positive and negative impacts on “hosts” and “immigrants” in all forms and at all levels. Cultural conflicts have been observed in various European and American nations. Coexisting within a diverse and multicultural community poses a novel and complex undertaking in the contemporary epoch.
The phenomenon of migrant workers from neighboring countries working in Thailand has also shown increasing trend. Currently, there are some negative signs of coexistence between Thais and migrant workers that could lead to ethnic and cultural conflicts if these are not managed properly and promptly. However, managing cultural diversity from the immigration of migrant workers has not received much attention.

Objectives:
1) To disclose the cultural diversity that has emerged in Thai society as a result of the influx of migrant workers from neighboring countries
2) To investigate the coexistence situation between the local Thais and migrant workers in Thai society, which exposes both positive and negative aspects of social relations and attitudes toward each other.
3) To develop "guidelines for building intercultural competence" to foster harmonious coexistence (a cohesive society) under the concept of "balanced multiculturalism" in the form of cultural media and activities that reduce conflict, promote mutual understanding and appreciation of diverse cultures; with the ultimate goal of establishing peaceful coexistence in Thai society.

Progress/Findings/Results:
The second year of the study surveyed attitudes and social interactions towards coexistence

among 1,060 Thai individuals and 1,016 migrant workers from Myanmar, Cambodia, and Laos in Bangkok, Pathum Thani, Samut Prakan, and Samut Sakhon, together with Observation and in-depth interviews.

The findings show that under the frame of coexistence in terms of acceptance, respect and appreciation, overall, Thai participants expressed neutral attitude towards coexistence with migrant workers. About half of Thai participants acknowledged that migrant workers are an integral part of Thai society and essential to the Thai economic development. Intermarriage between Thai and migrant workers is relatively acceptable, but migrant children born in Thailand are hesitantly accepted to be granted Thai citizenship. More than half of Thais support migrants' right to medical care, education, and the preservation of their cultural traditions. Protests for rights, however, are less tolerated because they are thought to provoke disturbance in Thai society. Concerning "appreciation," Thai participants expressed a modest level of appreciation for the presence of migrant workers, as it contributes to the diversity of ethnicities, languages, foods, and customs. Additionally, it provides opportunity for Thai people to gain exposure and enhance their ability to interact with different cultures. Regarding migrant workers' attitude, they exhibited a moderate level of acceptance of cultural differences when residing in Thai society, and they perceived the hospitality and acceptance of Thai people towards them at a neutral degree. As for the matter of "respect," the assessment mostly concentrated on compliance and adherence to laws and rules, encompassing legal immigration and work permit regulations. Workers from Myanmar and Cambodia had a pessimistic mindset, but workers from Laos maintain a neutral disposition. This could be attributed to language barriers both the workers themselves and the Thai government, who failed to give sufficient and accessible information on legislation. In addition, the tolerance of legal transgressions by government personnel might lead to uncertainty or misunderstanding among migrant workers.

Although several dimensions of migrant worker were acceptable and appreciated, Thai participants experience feelings of threat or unease, especially in Samut Sakhon where the ratio of migrant workers to Thais was the highest among the provinces under the study. The assessment of the perceived threat was based on concerns regarding the rising influx of migrant workers, competition for employment opportunities, the financial burden on the country to provide education and medical care for migrant workers and their dependents, the safety of life and property, environmental problems, and the increased congestion in public areas or services due to the growing number of migrant workers. In addition, Thais exhibit a neutral attitude towards the issue of discrimination, with an equal number of individuals expressing agreement and disagreement on the following matters: migrant workers should not be entitled to equal wages or welfare as Thai citizens, discriminatory towards migrant workers is perceived as common practices, and they are viewed as contributors to social alienation and the spread of epidemics. This is in line with what was reflected by migrant workers who perceived that they were stereotypically viewed by Thai people in various dimensions. Specifically, workers from Myanmar, they felt that they were more commonly stereotyped compared to workers from Cambodia and Laos. This is likely because their greater numbers relative to the other two countries, resulting in them often being the target of stereotypes. Furthermore, over a half of migrant workers of all nationalities reported that they experienced discrimination, prejudice and violence.

Conclusion:

The prevailing neutral disposition of both Thais and foreign workers poses a challenge, as it has the potential to shift downwards to negativity or develop upward positivity. Hence, it is imperative for Thailand to prioritize its efforts towards advancing in a more favorable direction by mitigating the potential for interpersonal conflict in coexistence. The focus is

suggested on fostering communication and facilitating interaction opportunities to achieve mutual understanding. Moreover, Thailand must prioritize the fundamental concern of promoting harmony by refraining from engaging in discriminatory, prejudiced, disrespectful, or threatening behavior toward migrant workers, as these matters are considered as a disregard for social justice and lead to social exclusion.

Current Output:

Challenges/Problems and Possible solutions:

The allocation of research funds is experiencing significant delays, resulting in researchers having to personally finance their expenditures in advance.

The enhancement of timely fund release by the funding source has the potential to facilitate researchers in adhering to their planned work schedules.

Future plan:

The data obtained from the first and second years of the project will serve as crucial information for developing intercultural competency among Thai individuals and foreign workers in the third year under the underlying concept of "balanced multiculturalism." In the last phase, the Participatory Action Research (PAR) methodology will be employed to facilitate collaboration between Thai and migrant workers to collectively identify and address challenges and develop strategies for fostering intercultural competency. This approach seeks to cultivate mutual understanding, promote a positive attitude toward coexistence, and encourage behaviors demonstrating respect for cultural diversity through cultural activities and media distribution on various platforms.

BRAINPOWER CONGRESS 2023

ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Medical AI, Immunology, Biomarker, Tissue Engineering)

Development of Deep-learning Platform for Structure-based Antibody Design for Immunotherapy and Biotherapeutic Applications

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Project duration: 2 years, from 1 August 2022 to 31 July 2024

Current progress: 50%

Abstract:

We are developing a deep-learning platform that facilitates the structure-based design of antibodies specific for antigens of interest. This in silico design of antibody offers an advantage to direct the epitope important to desirable bioactivity for immunotherapy and biotherapeutic applications. Currently, four targets are being explored: SARS-CoV-2 spike, RSV F, human PD-L1, and *Naja kaouthia* α-cobratoxin.

We have created antibody loop libraries from around 700 selected crystal structures of antibodies of moderate to high resolution from the Protein Data Bank and designed some antibodies for SARS-CoV-2 spike. Expression vectors for bacterial expression have been generated and those for yeast and mammalian expression are being made. Pseudotyped lentivirus and mRNA platforms for SARS-CoV-2 neutralization assay and in vivo studies have also been set up. Preliminary preparation of AbX-Fab from bacteria suggested that its quaternary structure contained both heavy and light chains. Based on this, studies on other antibodies are underway.

Rationales/Problem statements:

Cutting-edged technology and knowledges on biochemical reactions and pathways have significantly advanced the processes of antiviral drug development over the past decades. However, the emergence of SARS-CoV-2 has shown that the development of new antivirals is far too slow to compare with the rate of pandemic spread of COVID-19 and that new technologies are required for preparedness for the next emerging diseases. Usage of monoclonal antibodies in immunotherapy and diagnosis is gaining interest in the past decade. Yet, large parts of the current antibody development still rely on random processes such as immunization, library screening, or usage of convalescent sera. With the rapid progress in structural biology at present, information on pathology of infection and three-dimensional structures of target antigens for diagnosis or treatment can be determined very quickly. These offer a new process for therapeutic antibody development.

Objectives:

1. To pursue a new antibody development process using a deep-learning platform to facilitate the structure-based antibody design based on available three-dimensional structures from the Protein Data Bank for an automate or semi-automate design algorithm.
2. To design antibodies for target antigens using the information outlined above
3. To prepare, purify, and assay for binding affinities of the designed antibodies towards their specific antigen targets to validate the design algorithm.

Progress/Findings/Results:

Due to unexpected circumstances, the start of this project was delayed for about 6 months. However, we are trying to focus on the development of platforms required to accomplish the project in parallel and hope to meet the objectives as planned.

Using around 700 selected crystal structures of antibodies of moderate to high resolution from the Protein Data Bank (PDB), we have created antibody loop libraries to be used in our structure-based antibody design algorithm. The deep-learning algorithm is being developed, which will use the three-dimensional structural information from the libraries to generate variable loops on the designed antibodies that would provide binding specificity towards target antigens. Some antibodies for SARS-CoV-2 spike have been manually designed to initiate the design process. As we are aiming to produce the designed antibodies in Fab or IgG constructs, parallel expression systems for these are explored using *Escherichia coli* cells for bacterial expression and HEK293T cells for mammalian expression. We have also developed a new yeast strain that can grow to twice the cell density of *E. coli* in 2 days, which is also used for yeast expression system. Expression vectors for bacterial expression have been generated and those for yeast and mammalian expression are being made. Pseudotyped lentivirus and mRNA platforms have also been set up for SARS-CoV-2 neutralization assay and *in vivo* studies. Preliminary preparation of AbX-Fab from bacteria suggested that its quaternary structure contained both heavy and light chains. Based on this, antibodies AbY, AbZ, and AbG are being produced and purified. Additionally, antibodies specific for other targets are being designed.

Conclusion:

Several platforms required for the studies have been set up, and the remaining ones are under development. The current major challenges are on antibody production and verification of their quaternary structures. We are expecting that we can submit patent applications and publications on some of the findings, i.e. the new yeast expression system; deep-learning algorithm on antibody design; and specific antibody design and development.

Current Output:

The project is ongoing. There is no claimable output at the moment.

Challenges/Problems and Possible solutions:

Expression of antibodies in their correct quaternary structures are challenging. We are developing a simple and effective way to validate their quaternary structures.

Future plan:

We are focusing on development of the deep-learning algorithm for the structure-based antibody design, in parallel with the wet-lab verification of the designed antibodies. Expression vectors are being modified to incorporate both heavy-chain and light-chain genes into a single plasmid for yeast and mammalian expression and to improve expression yield and allow for easy verification of the quaternary structure for *E. coli* expression. Additionally, design of antibodies specific for other targets are ongoing.

The Use of Three-Dimensional Convolutional Neural Network (3DCNN) in Combination with Quantum Chemistry and IM-MS For Accurate Compound Identifications and Properties Predictions of Isomeric Lipids

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Project duration: 3 year, from 1 August 2022 to 31 July 2025
Current progress: 70%

Abstract:
In this study, for the first time, we propose to develop a novel three-dimensional convolutional neuron network (3DCNN) along with the existing DNN model for the accurate CCS prediction of isomeric lipid metabolites. To achieve this, we will use the state-of-the-art ultra-high performance liquid chromatography coupled to traveling wave ion mobility quadrupole time-of-flight mass spectrometry (UPLC-IM-Q-TOF-MS) to generate the reference CCS values from the lipid standards. Secondly, the 3D molecular structures will be calculated through the quantum chemistry approach. The results at this stage will be further used as inputs for our deep learning models. Since many molecules continuously change their confirmations while traveling through an ion mobility chamber, the continuous changes in 3D molecular structures of the lipids will also be studied using quantum chemistry calculations, and the obtained information will be used in fine-tuning the 3DCNN model to achieve optimal accuracy. Finally, we will demonstrate the use of our novel prediction model in identifying lipids isomers in the plasma samples of DKD patients.

Rationales/Problem statements:
Lipidomics research proves to be valuable in uncovering metabolic irregularities in diseases. Recent progressions in ion mobility mass spectrometry (IM-MS) technology have enhanced various aspects of lipid investigation, yielding potential biomarkers for early disease diagnosis and a deeper comprehension of disease-related molecular and metabolic processes. Despite the advantages of IM-MS in lipid separation and identification, the practical measurement of collision cross-section (CCS), a pivotal parameter for lipid compound separation and identification, remains limited. Thus, our project's objective is to create an innovative three-dimensional convolutional neural network (3D CNN) model for predicting the CCS of lipid metabolites, encompassing both isomeric and isobaric lipids. This model will be trained using reference CCS values, obtained through ultra-high-performance liquid chromatography coupled with traveling wave ion mobility quadrupole time-of-flight mass spectrometry (UPLC-TWIM-MS), while quantum chemistry calculations will determine the 3D molecular structures. Ultimately, the aim is to showcase this model as a novel approach for identifying lipids in plasma samples from patients with diabetic kidney disease (DKD).

Objectives:

- To develop a novel deep learning model for accurate predictions of the rotationally averaged collision cross-section values of lipid metabolites
- To identify lipid isomers in plasma samples from DKD patients using the developed deep learning model

Progress/Findings/Results:

This report covers the progress made from month 6 to 12 in our ongoing project. Our focus is on building a 3D CNN model to predict CCS values, aiding the discovery of potential lipid biomarkers in DKD patients. During this period, we optimized a UPLC-IM-MS method for measuring lipid CCS and conducted additional measurements on 40 lipid reference

standards. We also expanded the calculation and translation of 3D molecular structures, resulting in a broader dataset for our 3D CNN model development. This effort produced 2,925 2D images that represent the 3D molecular structures' shadows. The experimental CCS measurements and generation of 2D images are still an on-going process in order to achieve the maximum amount of training dataset. Moreover, we achieved significant progress in developing the initial 3D CNN model for predicting CCS values. The early results demonstrate competitive prediction accuracy with an error of 2-5%, even when trained with a relatively small number of molecules for a deep learning model. We are confident that by increasing the dataset and refining the model architecture, we can enhance this accuracy further and achieve our goal.

Although the core of our study involved developing a 3D CNN model to predict lipid CCS values, we also propose to explore potential biomarkers in plasma samples from individuals with diabetic kidney disease (DKD). Detecting small lipids like SCFAs using LC-MS, especially with ion mobility spectrometry, is challenging due to their small sizes and potential sensitivity issues. To address this, we developed a straightforward, robust, and accurate Gas Chromatography coupled with Time-of-Flight Mass Spectrometry (GC-TOFMS) method optimized for large cohort studies to comprehensively detect SCFAs in human plasma. A manuscript is currently under review.

Conclusion:

In conclusion, the project is moving forward in line with the intended proposal; the majority of the technological developments have now been finished, and we are prepared to begin actual sample analysis.

Current Output:

- CCS measurement of various standards (N=165)
- 26,700 two-dimensional images representing the molecular shadows from various angles of 1,780 molecules
- 1x Deep learning model under development
- 1x Manuscript under review
- Method and protocol for fecal short-chain fatty acid analysis by GC-TOFMS
- Method and protocol for plasma short-chain fatty acid analysis by GC-TOFMS

Challenges/Problems and Possible solutions: No

Future plan:

Our next step involves refining and optimizing the prediction model, ensuring an average error of less than 3%. Following this, the model will be applied to predict CCS values for all molecules encompassed in the Human Metabolome Database (HMDB), which includes over 200,000 compounds. We also plan to establish an online database housing the predicted CCS values. Additionally, we will fine-tune the model utilizing in-house measured CCS values of lipid standards. Finally, we will develop an IM-MS method and demonstrate the use of our model tailored to our experimental setup for lipid annotation in plasma samples from patients with diabetic kidney disease.

Development of Ion Mobility-mass Spectrometry and Artificial Intelligence for Medical Metabolomics to Aid Precision Medicine in Patients with Kidney Diseases

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 60%

Abstracts:

In this proposal, we aim to extend our investigation on CKD metabolomics analysis by 1) developing analytical methods based on ion mobility-MS (IM-MS) for quantification of low molecular weight metabolites, 2) establishing a four-dimensional IM-MS database, 3) developing deep learning architectures to integrate metabolomics, pathological, and clinical data, 4) applying the developed methods to search for metabolite biomarkers for primary glomerulonephritis (GN), i.e., IgA nephropathy (IgAN), focal segmental glomerulosclerosis (FSGS), membranous, minimal change, and lupus nephritis (LN), and other pre-dialysis CKD and gain deeper understanding of the role of the metabolites in the pathogenesis of the diseases.

Rationales/Problem statements:

Precision medicine has gained increasing attention in Thailand in recent years; however, the majority of research efforts have focused on the human genome, while research into the human metabolome (metabolomics) is still in its infancy. Chronic kidney disease (CKD) is a major health problem in Thailand requiring extensive medical care that, over time, can become a significant economic burden. One of the major challenges regarding CKD from a clinical perspective is the lack of sensitive and non-invasive biomarkers for detecting early stages. Our recent metabolomics study on CKD reported the potential use of the urinary ratio of picolinic acid to tryptophan ([Pic/Trp]), metabolites in the kynurenine pathway, for lupus nephritis (LN) diagnostic and membranous classification. The ratio of [Pic/Trp] has high potential as an alternative non-invasive biomarker for the diagnosis of LN. However, additional studies with long-term follow-ups are needed to establish the clinical use of the proposed biomarker.

Objectives:

1 To develop analytical methods-based ion mobility-mass spectrometry (IM-MS) for quantification of very low-molecular weight metabolites
2 To establish a four-dimensional IM-MS database of metabolites.
3 To develop deep learning (DL) architectures to integrate metabolomics, pathological, and clinical data
4 To apply the results from 1,2,3 to search for metabolite biomarkers for primary GN and LN, and other pre-dialysis CKD and gain better understanding about the role of important metabolites in primary GN and LN patients and CKD.

Progress/Findings/Results:

1. The development of IM-MS method for the measurement of very low-molecular-weight metabolites and IM-MS database for the applications of human urine samples.

In brief, we develop an analytical method using ultrahigh-performance liquid chromatography coupled to a traveling wave ion mobility-quadrupole-time-of-flight mass spectrometer optimized for the measurement of VLMs in human urine samples. We report the experimental CCS values and other mass spectral properties of the 174 metabolites. The experimental data included the mass-to-charge ratio (*m*/*z*), retention time (RT), tandem MS (MS/MS) spectra, and CCS values. Among the studied metabolites, 263 traveling wave ion mobility spectrometry (TWIMS)-derived CCS values ($^{TW}CCS_{N2}$) were reported for the first time, and more than 70% of these were CCS values of VLMs. The $^{TW}CCS_{N2}$ values were highly repeatable, with inter-day variations of < 1% RSD. The developed method revealed excellent $^{TW}CCS_{N2}$ accuracy with a CCS difference (ΔCCS) within ±2% of the reported drift tube IMS (DTIMS) and TWIMS CCS values. The complexity of the urine matrix did not affect the precision of the method, as evidenced by ΔCCS within ±1.92%. According to the Metabolomics Standards Initiative, 55 urinary metabolites were identified with a confidence level of 1. Among these 55 metabolites, 53 (96%) were VLMs. The larger number of confirmed compounds found in our study was a result of the addition of $^{TW}CCS_{N2}$ values, which clearly increased metabolite identification confidence.

The manuscript entitled "***Measurement of very low-molecular weight metabolites by traveling wave ion mobility and its use in human urine samples***" is under revision at the Journal of Pharmaceutical Analysis (Impact Factor = 8.8, Top 2.3% (1/43) of the area of Pharmacy). The IM-MS database is named Siriraj Metabolomics Data Warehouse (SiMD) can be found at http://www.metsysbio.com/simd/

2. The development of matching learning for metabolomics data handling.

In brief, in classic semi-quantitative metabolomics, metabolite intensities are affected by biological factors and other unwanted variations. A systematic evaluation of the data processing methods is crucial to distinguish adequate processing procedures for a given experimental setup. Current comparative studies are mostly focused on peak area data, but not on absolute concentrations. In this study, we evaluated data processing methods to produce outputs that were most similar to the corresponding absolute quantified data. We examined the data distribution characteristics, fold difference patterns between two metabolites, and sample variance. We used two metabolomic data sets from a retail milk study and a lupus nephritis cohort as test cases. When studying the impact of data normalization, transformation, scaling, and combinations of these methods, we found that the cross-contribution compensating multiple standard normalization (ccmn) method, followed by square root data transformation, was most appropriate for a well-controlled study such as the milk study data set. Regarding the lupus nephritis cohort study, only ccmn normalization could slightly improve the data quality of the noisy cohort. Since the assessment accounted for the resemblance between processed data and the corresponding absolute quantified data, our results denote a helpful guideline for processing metabolomic data sets within a similar context (food and clinical metabolomics). Finally, Metabox 2.0 was introduced, which allows the thorough analysis of metabolomic data, including data processing, biomarker analysis, integrative analysis, and data interpretation. It was successfully used to process and analyze the data in this study. An online web version is available at http://metsysbio.com/metabox.

The manuscript entitled "Metabox 2.0: The data processing solution that renders metabolomics more quantitative" is now under review at GigaScience [Impact Factor = 7.658, Top 1.5% (12/781) in the area of Computer Science Applications].

3. The development of matching learning to predict ion mobility collision cross section

In brief, the rotationally averaged collision cross-section (CCS) determined by ion mobility mass spectrometry (IM-MS) facilitates the identification of various biomolecules. Although machine learning (ML) models have recently emerged as a highly accurate approach for predicting CCS values, they rely on large datasets from various instruments, calibrants, and setups, which can introduce additional errors. In this study, we identified and validated that the ion's polarizability and mass-to-charge ratio (*m/z*) have the most significant predictive power for traveling-wave IM CCS values compared to other physicochemical properties of ions. Constructed solely based on these two physicochemical properties, our CCS prediction model demonstrated high accuracy and robustness, achieving a mean relative error (MRE) of 2.0% when trained with only 15 experimental CCS values in the positive ion mode and 65 in the negative ion mode, respectively. Given its ability to excel with limited data, our approach harbors immense potential for constructing a precise predicted CCS database tailored to each distinct experimental setup. A Python script for CCS prediction using our approach is freely available at https://github.com/MSBSiriraj/SVR_CCSPrediction under the GNU General Public License (GPL) version 3.4).

The manuscript entitled "Accurate prediction of Ion Mobility Collision Cross Section using Ion's polarizability and molecular mass with limited data" is now under the review at the Journal of Chemical Information and Modeling [Impact Factor = 5.6, Top 10% (31/325) in the area of Chemical Engineering (miscellaneous).

4. Review article on the analysis of gut microbial metabolites of aromatic amino acids by mass spectrometry

Aromatic amino acids (AAA) and their gut microbiota-derived metabolites have emerged as significant metabolites that affect the gut and distant organs and have been linked to several diseases. In response to the increasing interests in the roles of these microbial metabolites, numerous analytical methods have been recently developed. To our knowledge, mass spectrometry-based metabolomic methods for gut microbial AAA metabolites have not been reviewed. The scope of this review is to summarize recent development of MS-based methodology for the analysis of gut microbiota-derived AAA metabolites during the past five years. In brief, small molecules derived from gut microbiota have been increasingly investigated to better understand the functional roles of the human gut microbiome. Microbial metabolites of aromatic amino acids (AAA) have been linked to many diseases, such as metabolic disorders, chronic kidney diseases, inflammatory bowel disease, diabetes, and cancer. Important microbial AAA metabolites are often discovered via global metabolite profiling of biological specimens collected from humans or animal models. Subsequent metabolite identity confirmation and absolute quantification using targeted analysis enable comparisons across different studies, which can lead to the establishment of threshold concentrations of potential metabolite biomarkers. Owing to their excellent selectivity and sensitivity, hyphenated mass spectrometry (MS) techniques are often employed to identify and quantify AAA metabolites in various biological matrices. Here, we summarize the developments over the past five years in MS-based methodology for analyzing gut microbiota-derived AAA. Sample preparation, method validation, analytical performance, and statistical methods for correlation analysis are discussed, along with future perspectives. The review has been published entitled "Mass Spectrometry-based Analysis of Gut Microbial Metabolites of Aromatic Amino Acids. Comput. Struct Biotechnol. 21:4777-4789." [Impact factor = 6.0, Top 10% (10/147) in area of Biophysics.

Conclusion:

In occlusion, the progress of this project is going according to the purposed proposal, we are now completed most of the technology developments and now ready for real sample analysis. We expect to complete the sample analysis within the next six months.

Current Output:

- 1x Review article published: https://doi.org/10.1016/j.csbj.2023.09.032
- 3x Manuscripts submitted
- 5x Highly-trained researchers in the area of IM-MS, bioinformatics, CKD research
- Analytical protocol for the measurement of metabolites in urine samples by IM-MS
- IM-MS database for metabolite identification (SiMD)
- Online Metabox II
- A software DeepSimProfiler (DSP) for data analysis

Challenges/Problems and Possible solutions:

- Problem with the sample collection i.e., IRB and etc.

Future plan:

We are now applying all the developed technology i.e., MS analytical methods and bioinformatic tools for metabolomics analysis of plasma and urine samples from patients with IgA nephropathy (N=70), focal segmental glomerulosclerosis (N=50), membranous (N=40), minimal change (N=40), and lupus nephritis (LN=170), and other pre-dialysis CKD (N=400).

Alt-Spec: Protein Engineering Altered Protein-Ligand Specificity by a Convolutional Neural Network

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Project duration: 3 years, from 1 August 2022 to 31 July 2025
Current progress: 40%

Abstract:

Improving pharmaceutical manufacturing involves not only enhancing production but also facilitating the transition to sustainable practices, thereby reducing the environmental impact of drug synthesis. Enzymatic processes offer a more sustainable approach, enabling the efficient and precise synthesis of active pharmaceutical ingredients (APIs) under gentler conditions. However, traditional enzyme design methods are time-consuming and expensive, limiting their widespread adoption.

To address this, we have employed predictive models and computational analyses of sequences/structures to streamline enzyme screening and expedite the design of enzymes tailored for specific API synthesis. This study focuses on the development of computational approaches utilized in engineering lipases for synthesizing molnupiravir as a study model. Our research has yielded promising novel lipases demonstrating equivalent activity for molnupiravir synthesis in comparison to the widely used CalB lipase. Further development of computational methods and thorough characterization of the engineered enzyme are currently underway, aiming to optimize its performance.

Rationales/Problem statements:

Traditional chemical synthesis methods often utilize harsh conditions and toxic reagents, contributing to environmental pollution and the generation of unwanted byproducts. Enzymes, however, present an eco-friendlier alternative by enabling the production of APIs efficiently and specifically under mild reaction conditions. Their tailored use allows the synthesis of complex molecules that might otherwise be challenging through conventional chemical routes. Yet, the labor-intensive and time-consuming nature of traditional enzyme design limits success rates and escalates costs. This initiative seeks to harness computational tools to streamline the process, accurately predicting enzyme behavior and substrate specificity. The goal is to expedite the design and screening of enzymes customized for specific API synthesis, thereby enhancing enzymatic performance, selectivity, and stability.

Integrating computational modeling with experimental validation aims to revolutionize pharmaceutical synthesis, offering a cost-effective, sustainable, and precise approach to producing APIs. This endeavor not only boosts production but also supports the shift towards a bio-circular green economy, aligning with sustainable practices and reducing ecological footprints in drug synthesis.

Objectives:

- Create a database housing experimental protein variant binding affinity.
- Develop a computational approach predicting alterations in protein-ligand binding.

- Validate the platform's utility and integration into practical protein engineering workflows.

Progress/Findings/Results:

We identified two bacterial lipases sharing significant structural resemblance to the fungal CalB, a widely employed biocatalyst, despite having less than 40% sequence identity. Partial purification was carried out, enabling a comparison of the enzymatic traits of these potential lipases with CalB. One of the candidates exhibited an optimal pH of 8 and a temperature optimum of 50°C, akin to CalB. Meanwhile, the second candidate displayed an optimal pH of 8, with a higher temperature optimum of 55°C. Notably, this second candidate sustained considerable activity even under extreme conditions, maintaining high functionality at 70°C or pH 9, which contrasted sharply with the reduced activity observed in CalB under similar circumstances. While the wildtype candidate initially showed no activity in molnupiravir synthesis, the first batch of engineered candidates successfully produced the desired products equivalent to CalB.

However, the protein expression levels of these candidates remained relatively low, posing challenges for their purification, characterization, and suitability for industrial applications. Despite attempts to optimize through experimental means, such as changing hosts, vectors, and media, the enhancement in production was not significant. Computational methods were thus employed to enhance protein stability. Subsequently, the engineered lipases exhibited a significant improvement in protein expression. Efforts are currently ongoing to engineer these lipases for molnupiravir synthesis.

Simultaneously, we developed a predictive model for protein-ligand binding affinity based on a mutation dataset. Two databases were compiled: the first comprised 5,316 protein-ligand complexes with binding affinities represented by Ki or Kd, while the second contained 1,020 complexes with delta delta G (ddG) binding affinities. Additionally, we curated a collection of CalB with Km binding affinity (166). However, the correlation between predicted and experimental values was unsatisfactory. To further develop the model, we intend to explore classification methods instead of regression prediction. Moreover, other machine learning algorithms will be employed, considering that the current datasets might not suffice to train CNN algorithms.

Conclusion:

In conclusion, our investigation identified promising bacterial lipases resembling the fungal CalB, showcasing diverse enzymatic characteristics and resilience under extreme conditions for potential industrial applications. Despite challenges in protein expression, our engineered candidates exhibited substantial improvement, particularly in molnupiravir synthesis.

Current Output:

Nongluck Jaito, Nattha Kaewsawat, Suthathip Phetlum, and Tanaporn Uengwetwanit, (2023) Metagenomic discovery of lipases with predicted structural similarity to *Candida antarctica* lipase B, PlosOne

Future plan:

- Apply for intellectual property.

Development of Differential Dynamic Microscopy Measuring Instrument for Hypercoagulation and Viscosity Assessment of Biological Fluid by Estimating of Non-Newtonian Behavior with Deep Neural Networks

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Project duration: 1.5 years, from 1 August 2022 to 31 January 2024

Current progress: 80%

Abstract:

An emerging differential dynamic microscopy (DDM) technique has been successfully used for quantitative dynamic investigation of micro-particle suspensions, leading to a rheological assessment of the solution. This technique exploits an optical microscope equipped with a digital camera for the assessment. However, the shallow focal plane on high-power objectives leads to an unreliable result as image noise becomes a significant presence. To overcome this limitation, we developed a heterodyne near-field scattering device for use in DDM in which the emitted beam interferes with the scattered light by the particles. Moreover, we couple the device with a deep convolutional neural network to extend its measurement range and add more fuctionalities to it. Our device is compact and portable. It comprises a few main components and requires only 8 μL sample volumes for the rheological assessment. Thus, it is easy to relocate to measure biological samples, which often do not retain their natural properties in storage, allowing for studies of the fluids. In comparison, the obtained responses agreed with the reference bulky mechanical rheometer, although the employed partially coherent source and out-of-focus image acquisition bring difficulties to our system.

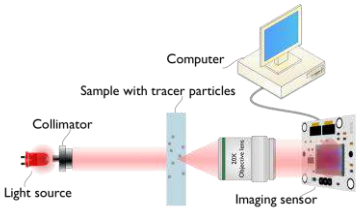
Rationales/Problem statements:

Integration with deep-learning frame interpolation can investigate the responses at extended measurement ranges that are beyond the limit of traditional DDM to develop an artificial saliva. In addition, our device can characterize whole blood samples without the need for dilutions to study whole blood viscosity between healthy individuals and clinically identified thalassemic subjects. Furthermore, an implemented deep-learning algorithm can classify these two groups among thalassemic subgroups based on their blood micromotion for prescreening applications. With the improvements in our device, characterization of the rheological responses for biofluid understanding, design, and development can be carried out in a cost-effective manner compared to a reference gold standard method (the mechanical rheometer).

Objectives:

- To develop a differential dynamic microscopy-based device for characterizing rheological response of biological fluids
- To develop and integrate a deep-learning algorithm into the developed device for extending the measurement ranges
- To investigate whole blood and plasma viscosity in Beta- thalassemia patients compared to normal adult.
- To study relationship between viscosity and hypercoagulation event in Beta-thalassemia
- To study viscosity of different artificial saliva formulas

Progress/Findings/Results:



This research can be summarized as follows:

• We developed an AI framework for extending the measurement ranges of our DDM device which are limited by the video frame rate of the camera, resulting in a limitation in investigating distinguish responses at the high-frequency region.

• Our device is comparable to commercial Rheometer on glycerol mixture, blood sample, artificial saliva sample

• We developed an AI model that can classify thalassemia patients and normal people based on their blood micromotion.

• Our device was used to measure blood and plasma viscosity of normal adults and beta thalassemia patients which implied to prognosis of hypercoagulation events in non-splenectomized and splenectomized beta thalassemia patients

Conclusion:

We developed a device based on differential dynamic microscopy (DDM) principle aiming at micro-rheological characterization of a fluid of interest. In contrast to typical DDM device, our device can perform light scattering experiment with a large depth-of-field. As a result, the focusing mechanism can be vanished, providing more in affordability and compactness in our device. When compared with a gold standard method (mechanical rheometer), our device microchamber consumes more than 100 times less sample and is inexpensive and disposable. Futhermore, we used Computer Vision models to extend measurement range and add more functionalities to the device. Applications of our device impact the blood and artificial saliva viscosity measurements which will benefit clinical implication and management.

Current Output: 1 Publication, 1 Patent Pending, 1 Prototype

Challenges/Problems and Possible solutions:

Blood: The period of sample storage affects the result and interpretation of platelet activation experiment. We have decided to repeatedly enroll and collect the blood, then immediately conducted the platelet activation assay.

Artificial Saliva: The artificial saliva formulation was modified due to the early precipitation of additives. The modified formulation included propolis and aloe vera extract to promote mineralization and moisturizing actions. The formulations were designed with low viscosity for spray rinses. However, the high viscosity formulation, used as a mouth gel, required improvement of the device to allow measurement of viscoelastic material in the high viscosity range

Future plan:

- Two manuscripts submit, revise, and publish
- Next: Vitreous Humor

Project title: Modifying Gut Microbiome by Synbiotics Toward Personalized Medicine for Non-Alcoholic Fatty Liver Disease and Chronic Kidney Disease

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Project duration: 3 years, from 1 April 2023 to 31 March 2026

Current progress: 7.5%

Abstract: Chronic kidney disease (CKD) and fatty liver disease (FLD) represent significant global health challenges, often linked to metabolic dysfunctions and chronic inflammation. The emerging role of gut microbiota in modulating disease progression has opened new therapeutic avenues. Previous studies showed that synbiotic treatment improved uremic toxins and renal osteodystrophy in CKD rats by promoting intestinal epithelial barrier and gut eubiosis. This study investigates the potential benefits of synbiotic supplementation in managing CKD and FLD. Synbiotics are hypothesized to modify gut microbiota composition, thereby reducing inflammation, improving metabolic profiles and gut leakage in affected individuals. We expected that participants receiving synbiotics could alleviate impaired kidney function, reduced liver fat deposition, and complications, and a favorable shift in gut microbiota composition. These findings could substantiate synbiotic supplementation as a complementary therapeutic strategy for these chronic diseases, offering a non-invasive, cost-effective approach to improve patient outcomes and quality of life.

Rationales/Problem statements: Chronic kidney disease (CKD) and fatty liver disease (FLD) are escalating global health concerns, significantly contributing to morbidity and mortality worldwide. CKD, characterized by progressive loss of renal function, leads to end-stage renal disease, necessitating dialysis or transplantation. Fatty liver disease, often associated with obesity and diabetes, can progress to liver cirrhosis and cancer. Current drugs are partially effective in alleviating the disease progression. The advent of synbiotics offers a novel therapeutic perspective. Synbiotics are known to enhance gut microbiota balance and gut barrier, which is crucial in metabolic regulation and inflammatory response modulation. Synbiotics have been proven to improve clinical in several diseases by enhancing gut eubiosis and gut barrier, mitigating systemic inflammation and metabolic disturbances, thus potentially slowing disease progression, and improving prognosis. This approach could revolutionize the management of these diseases, emphasizing the importance of gut health in systemic chronic conditions, and lowering the economic burden of drugs.

Objectives:

1) To study the safety and efficacy of synbiotics in animals in preventing and alleviating fatty liver disease (FLD) and chronic kidney disease (CKD).
2) To investigate the safety and efficacy of synbiotics in alleviating diseases in patients with FLD and CKD.
3) To study the relationship between dietary data collected and gut microbiota and metabolites in FLD and CKD.
4) To develop the processing of gut microbiota data, nutritional information, and genetic data in conjunction with clinical data in assessing the severity of FLD and CKD.
5) To further develop synbiotics for commercial use as functional foods.
6) To develop a point-of-care testing kit for gut microbiota and metabolites associated with FLD and CKD.

Progress/Findings/Results: The progression was reported up to NOV 17th, 2023.

1. **Synbiotics:**

1.1 Two prototypes of synbiotics have been developed, for CKD and FLD each.
1.2 Probiotics have been tested for acid and alkaline-resistant tests.
1.3 Drug resistance tests of probiotics are undergoing.
1.4 Contacting the Thai FDA for information and guidance to register the synbiotics for human experiment & commercial uses.
1.5 Contacting private enterprises to synthesize synbiotics into dry powder form.
1.6 Contacting the IP service for patent/petty patent registration.

2. **Animal studies:**

2.1 Acute and subacute toxicity of synbiotics has been preliminarily reported: synbiotics have very low toxicity in increasing liver and kidney biomarkers. The histopathological examination is undergoing.
2.2 Testing the synbiotic effect in animal models: rats are undergoing the induction of FLD using a high-fat diet, and CKD using cisplatin and adenine.
2.3 IBC has been approved, and animal IRB has been finalized before approval.

3. **Human study:**

3.1 IRB has been approved.
3.2 Enrollment of participants is undergoing: FLD patients 150 cases (100%) and CKD 60 cases (30%) of the target population.

4. Utilization of the research

The poster presentation was done at the World of Microbiome Conference 2023, in Sofia, Bulgaria from 25-27, OCT, 2023

- Elucidating the gut microbiome profile as a discriminatory tool for distinguishing between viral-induced and non-viral-induced hepatocellular carcinoma

Conclusion: The synbiotic is safe. Further study in animals and humans will proceed as planned.

Current Output: (for example: Publication/patent/prototype)

Publications:

1. The usefulness of resistant maltodextrin and chitosan oligosaccharide in management of gut leakage and microbiota in chronic kidney disease. Nutrients 2023, 15, 3363 (Tier 1)
2. Long-term benefit of DAAs on gut dysbiosis and microbial translocation in HCV-infected patients with and without HIV coinfection. Scientific Reports (2023) 13:14413 (T1)
3. Gut microbiota in patients with non-alcoholic fatty liver disease without type 2 diabetes: Stratified by body mass index. Int. J. Mol. Sci. 2023, 24 (revised, T1)
4. Single and mixed strains of probiotics reduced hepatic fat accumulation and inflammation, and altered gut microbiome in a non-alcoholic steatohepatitis rat model (submitted).

Challenges/Problems and Possible solutions:

1. The delay in the pathological study due to the overload of staff in the Department of Pathology, Faculty of Medicine.
2. The delay in making the appointment with the Thai FDA due to the undefined definition of synbiotics according to Thai FDA regulations.

Future plan: for the next 6 months:

1. Synbiotics: complete testing of synbiotic properties, ready to register to Thai FDA
2. Animal study: complete the animal experiments, and get the laboratory result > 70%
3. Human study: complete the enrollment of participants and collection of biosamples
4. Publication: publish 2 or more manuscript2 in NCBI/Scopus database journals

Multi-omics Integration of Host Gene and Microbiome to Identify Novel Diagnostic Biomarkers for NAFLD-related Hepatocellular Carcinoma

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 50%

Abstract:
About 25-30 percent of the people with non-alcoholic fatty liver disease (NAFLD) develop liver cirrhosis and hepatocellular carcinoma (HCC). An ultrasound and alpha-fetoprotein can be used as markers to diagnose HCC. However, due to the limited of its sensitivity, finding new biomarkers could facilitate early diagnosis of HCC, particularly in NAFLD-related HCC. Previous studies showed that gut dysbiosis has been linked to changes in host gene regulation, which are relevant to the progression of liver diseases. Our study aimed to identify novel biomarkers for early diagnosis of HCC using multi-omics data integration between host and microbiome, which include 16S rRNA sequencing and transcriptomic profile. We expected that multi-omics analysis might help to identify microbial or gene biomarkers that are accurate and specific to each person (precision medicine). Moreover, these data will help us to understand the pathophysiology of the diseases and enhance host health or restore perturbance of gut microbiota.

Rationales/Problem statements:
Non-alcoholic fatty liver disease (NAFLD) is one of the health global issues, affecting around 25 percent of the world's population. NAFLD is frequently associated with metabolic syndrome and can progress to liver cirrhosis and hepatocellular carcinoma (HCC). There are many factors including age, gender, liver fibrosis, diabetes, obesity, genetic polymorphisms (single nucleotide polymorphisms; SNPs), host gene expressions, particularly in alteration of gut microbiota have been linked to the progression of liver diseases. The gut microbiome had functional roles in host metabolism and physiology. Moreover, many reports showed that genetic variation is associated with microbial abundance and their ecosystem. The host-microbiome interaction study could facilitate the better understanding of how the gut microbiome impacts or is impacted by host gene expression.

Objectives:
- To investigate gut microbiome profiles of HCC patients and control group.
- To investigate host gene profiles of HCC patients and control group.
- To explore the interaction of the host-microbe in HCC using bioinformatic tools.
- To identify the candidate biomarkers of host-microbe in diagnosis of patients with HCC.
- To validate the host gene expression, SNPs and bacteria abundance in clinical samples.

Progress/Findings/Results:

Our study was divided into 2 phases including discovery phase and validation phase. In this first progress report, the results were reported from discovery phase.

1. Ethical approval for human research has been approved by the institutional review board (IRB) from Faculty of medicine, Chulalongkorn University (IRB No. 0371/66).
2. Biological samples including blood and fecal were collected from healthy individuals, patients with NAFLD and patients with HCC.
3. DNA was extracted from fecal samples and sequenced by 16S rRNA sequencing for gut microbiota analysis.
4. RNA was extracted from blood samples and sequenced by RNA-sequencing for transcriptomic profile analysis. RNA from patients with NAFLD group was an ongoing process.
5. Clinical parameters were collected and analyzed with microbiome and host transcriptome data.
6. Host-microbiome interaction was analyzed, and candidate gene and bacteria were selected as diagnostic biomarkers in differentiating patients with HCC from healthy control.

- For host-microbiome interaction, we found bacteria in gut were related to LPS production and host genes were mainly involved in immune regulation pathway. Finally, based on machine learning approach, 4 genera of bacteria were revealed to be diagnostic biomarkers in discriminating non-viral-related HCC from viral-related HCC (AUC = 0.81). However, the performance in differentiating the non-viral and viral-related HCC of host genes was not satisfactory.
- For gut microbiota analysis, HCC group showed significantly decreased alpha-diversity and changed in microbial composition compared with healthy controls. There were 11 genera significantly enhanced in Viral-HCC, while 5 genera were enhanced in NBNC-HCC. Compared to Viral-HCC, the NBNC-HCC subgroup significantly reduced various short-chain fatty acid-producing bacteria, as well as declined fecal butyrate but elevated plasma surrogate markers of microbial translocation. Based on the machine learning algorithm, a high diagnostic accuracy to classify HCC subgroups was achieved with an area under the curve of 0.94.

Conclusion:

In host-microbe interaction analysis, the alteration of the abundance of specific taxa was associated with specific host gene expression. In gut microbiome analysis, we observed the link between reduced microbial diversity and SCFA-producing bacteria and severity of liver diseases. Collectively, these data revealed that gut dysbiosis was distinct according to etiological factors of HCC, which might play an essential role in hepatocarcinogenesis. These findings underscore the possible use of gut microbiota signature for the diagnosis and therapeutic approaches regarding different subgroups of HCC. The modulation of gut microbiota might improve gut homeostasis especially in patients with non-viral-related HCC.

Current Output:

1. Publication “Distinct alterations of gut microbiota between viral and non-viral-related hepatocellular carcinoma” in Applied Microbiology and Biotechnology (Q1)
2. Proceeding “Gut microbiome diversity and composition in hepatocellular carcinoma in Thai population” in the 11th College of Asian Scholars National and International

Conference 2023.

Challenges/Problems and Possible solutions:

1. Delay in sample and clinical data collection in patients with NAFLD, particularly in those patients who have severity of fibrosis stage. However, we planned to collaborate with doctor (hepatologist, radiologist and surgeon) more to enhance the chance of in collecting more specimens.

Future plan:

1. The RNA sequencing data from patients with NAFLD will be analyzed.
2. Complete the discovery and validation study in term of host-microbiome interaction.
3. The data will be published 2 more international publications at least for Q1 in Scopus database.

Multi-Institutional Artificial Intelligence Development in Digital Pathology

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Department of Pathology, Faculty of Medicine, Chulalongkorn University

Project duration: 3 years, from 1 January 2022 to 31 December 2024

Current progress: 67%

Abstract:

Histopathological imaging of patient tissues is a crucial investigative tool that enable precise diagnosis of important diseases, including cancer and tuberculosis (TB). However, visual inspection of histopathological images is highly time-consuming and prone to errors, especially for inexperienced pathologists. Artificial intelligence (AI) trained on large-scale and diverse histopathological image datasets can reduce time spent and improve the sensitivity of diagnosis by proposing regions of interest on the whole-tissue images that should be carefully scrutinized by pathologists. In this project, we combined tissue samples and expertise from the Faculty of Medicine, Chulalongkorn University and the Institute of Pathology, Ministry of Public Health to develop AI for five digital pathology applications, namely mitotic cell counting, HER2 expression assessment, cytomegalovirus infection, thyroid cancer subtyping, and TB screening. To ensure high quality of data labeling, preliminary AI models were built to propose cells and objects that pathologists might miss in their initial annotation.

Rationales/Problem statements:

- Visual inspection of extremely large (150,000 pixels x 150,000 pixels) histopathological images is highly time-consuming and prone to errors.
- Artificial intelligence models have demonstrated an ability to detect objects of interest and to interpret details in images that surpass human eyes.
- Even if it is not feasible to train AI models that can identify cancer or infected cells with the same accuracy as skilled pathologists, these AI models can still be used to propose regions of interest for pathologists, thus reducing the amount of time that a pathologist spent per image substantially.
- Each digital pathology application has different technical challenges and different workflows that integrate human interactions with AI assistance. Hence, we have selected five diverse tasks to focus on.

Objectives:

We are developing AI models that can assist pathologists in the following applications:

- Measure HER2 copy number and gene expression in breast cancer tissues.
- Count the number of mitotic figures in cancer tissues.
- Detect cells infected with cytomegalovirus.
- Detect TB in Ziehl-Neelsen stain.
- Diagnose papillary thyroid carcinoma.

Progress/Findings/Results:

Regarding data collection, gathering of the bulk of histopathological images for training AI model for each digital pathology application has been completed. Additional data (~300 cancer and ~300 normal tissues) were collected to address the limitation of AI prototypes in some applications. A two-round annotation scheme has been developed and deployed to let pathologists revise their initial annotations of cells and objects based on AI suggestion. Roughly 1,600 additional negatives and mitotic figures were annotated with this two-round strategy. Regarding AI development, the models were additionally trained to further recognize the context (background) surrounding each cell or object of interest. For diagnosis papillary thyroid carcinoma, the model is now trained to be able to segment tumor areas, not

just classifying the whole image. For mitotic figure counting, up to 4 percentage point increase in F1 score was obtained when switching from an object detection model to a segmentation model with context information from the surrounding of the cells.
For some digital pathology tasks, we have begun evaluating the AI alongside pathologists. For example, mitotic figure counting speed improved from an average of 46 minutes to 33 minutes when AI predictions were provided to pathologists. For cytomegalovirus infection, all positive cases were detected by examining just the top 20 most likely infected cells proposed by the AI. For HER2 grading, a prototype mobile application is being developed.

Conclusion:
Histopathological images are not difficult to collect but are difficult to accurately and completely annotate due to the large image size and diverse object classes. Technical variations from scanners and disagreements between human experts also considerably affect the behaviors of the AI. As we were aware of these limitations since day one, our efforts were spent on gathering data from multiple tissues, obtaining annotation from multiple pathologists, and utilizing immunostaining and molecular markers to obtain a gold standard annotation. Our AI prototypes will be tested alongside pathologists in actual service settings to evaluate robustness and benefits on the workflow.

Current Output:

- 1 publication (Artificial Intelligence in Medicine journal)
- 3 AI-based software prototypes and 1 digital pathology platform

Challenges/Problems and Possible solutions:

- AI models learn quickly to classify the majority of objects of interest, but it is difficult to improve the models on rarer objects.
- To deploy the AI, there are many other components that must be developed, such as a scalable database for scanned images, an analysis queue for AI models, and a user interface that allows pathologists to view and edit AI's predictions.

Future plan:

- Perform error analysis of AI prototypes to pinpoint additional tissue samples that should be collected to improve the models.
- Implement an end-to-end platform that will allow pathologists to test AI prototypes in real service settings.
- Publish the refined AI for each digital pathology application.
- Create a database of well-annotated histopathological images that will be useful for other researchers.

Identification of Candidate Biomarkers for Precision Medicine in Autism in Thai Population

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 48%

Abstract:

Autism Spectrum Disorder (ASD) is a neurodevelopmental disability characterized by a high degree of heterogeneity. Presently, the cause of ASD remains unknown. Understanding the genetics of individuals with ASD, including their parents, might contribute to a better understanding of the origin of ASD. This research aims to elucidate the genetic underpinnings of individuals with ASD by applying a multiomics approach—genetics trio, transcriptomics, and proteomics. The primary focus is on identifying potential genetic causes, biomarkers, candidate genes, and associated proteins contributing to ASD manifestation. Additionally, the research integrates machine learning techniques to systematically screen and subgroup individuals based on clinical symptoms, enhancing precision in diagnosis and treatment strategies. Through the integration of advanced molecular analyses and artificial intelligence, this study seeks to shed light on the intricate molecular aspects of ASD. The findings hold promise for targeted interventions and personalized therapeutic approaches in the realm of neurodevelopmental disorders.

Rationales/Problem statements:

Autism Spectrum Disorder (ASD) is a prevalent neurodevelopmental condition characterized by a range of symptoms impacting social interactions, communication, and behavior. The rising prevalence of ASD poses a significant public health concern. The disorder's etiology remains elusive, attributed to a complex interplay of genetic and environmental factors. Present diagnostic methods relying on behavioral observation are limiting and can cause delays in intervention. Emerging evidence suggests distinct gene and protein expression patterns correlating with symptom severity in individuals with ASD. This study employs a multiomics approach to unravel the genetic intricacies of ASD. The research aims to pave the way for personalized therapeutic interventions, addressing the heterogeneity within ASD subpopulations.

Objectives:

1. To develop a machine learning prototype for the screening and subgrouping of Thai individuals with ASD based on their clinical symptoms.
2. To investigate the transcriptome profiling of Thai individuals with ASD within the severe group categorized by machine learning.
3. To investigate the proteome profiling of Thai individuals with ASD within the severe

group categorized by machine learning.
4. To examine the genetic polymorphisms associated with ASD within the Thai population.
5. To integrate multiomics analyses, predicting the associations between genes/proteins and biological functions. To discover biomarkers for ASD screening and address the heterogeneity within ASD subpopulations.

Progress/Findings/Results:

Specimen collection

Our study (COA No.1238/2022) received approval from the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand. With a total of 300 participants enrolled, including 186 individuals in the ASD group (ages 2-18, Thai ethnicity, diagnosed with ASD based on DSM-V and CARS-2 criteria; 2 of them were excluded) and 114 in the typical control group (ages 2-18, Thai ethnicity, showing no ASD symptoms; 4 of them were excluded), we have collected 184 ASD specimens and 110 control specimens to date.

Machine learning development

In ASD screening, data from 150 ASD individuals and 100 controls were used to develop a machine-learning model. Random Forest and k-Nearest Neighbour achieved high performance with 99.20% accuracy, 99.32% sensitivity, and 98.98% specificity. When deployed with 44 unknown samples, only one incorrect prediction occurred. In ASD subgrouping, the k-means algorithm efficiently divided the dataset into four distinct subgroups by demonstrating the lowest average within-centroid distance.

Transcriptomics analysis

A total of 189 RNA samples, obtained from 127 individuals diagnosed with ASD and stratified into subgroups by machine learning, along with 62 control samples matched for age and sex in each subgroup, have been sent to the BGI company for RNA sequencing. To date, RNA-sequencing analysis has been completed, and we are currently engaged in the bioinformatic analysis of RNA-sequencing raw data. The results of the sequencing will be summarized by the end of November.

Proteomics analysis

As of November 20, a total of 276 protein samples, derived from 168 individuals diagnosed with ASD and 108 individuals representing typical controls, were prepared for shotgun proteomics analysis. This study will be conducted in cooperation with Dr. Sittiruk Roytrakul at the National Science and Technology Development Agency (NSTDA).

Trio study (whole genome sequencing)

As of November 20, 2023, specimens from 108 individuals diagnosed with ASD and their parents have been collected and forwarded to Genomics Thailand for whole-genome sequencing.

Conclusion:

To date, we have collected 184 specimens from ASD individuals and 110 control specimens. Among these, 63 ASD participants underwent multiomics analyses. In machine learning development, Random Forest and k-nearest Neighbour models demonstrated superior performance for ASD screening, while the k-means algorithm proved effective for subgrouping individuals with ASD.

Current Output:

Machine learning prototype for ASD screening and ASD subgrouping and RNA-sequencing data of ASD and TD individuals (189 samples)

Challenges/Problems and Possible Solutions: Whole genome sequencing cannot be performed for age- and sex-matched controls. Instead, genome data from a genomic database will be utilized.

Future plan:

We will complete specimen collection for the Genomics Thailand project by the end of this year. Transcriptome and Ingenuity Pathway Analysis of RNA-sequencing data for ASD individuals and their subgroups will be finished by the end of November. Currently, we are preparing protein samples for shotgun proteomics and DNA samples for the Infinium Methylation EPIC Array.

Phage Display Biotechnology: Identification of a Novel Target for Lung Cancer Therapy

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 40 %

Abstract: Antibodies and antibody-based immunotherapeutics are the mainstays of cancer immunotherapy. Expanding the repertoire of cancer-specific and cancer-associated epitopes targetable with antibodies represents an important area of research. In this study Yamo I, a diverse compact phage library of scFv fragments derived from human naïve antibody variable gene fragments was screened against human immortalized cell line HEK293T. As a result, scFv N11 was isolated, and its ability to bind the appropriate cell targets was confirmed. Upon engineering to IgG1 and BiTE, N11 in either format showed interaction against a broad panel of human cancer cell lines. Flow cytometry analysis against normal human PBMCs, suggesting a low risk of autoreactivity and provides preliminary evidence of N11 safety. CRISPR/Cas9-based library screening technique was used to identify the cell surface target antigen. This work, therefore, may help identify novel cancer-associated molecules as well as provide effective immunotherapeutics to target malignant cells in cancer patients.

Rationales/Problem statements: Research for novel lung cancer medicines is vital due to its high incidence and mortality rates, urging the need for more effective treatments. Current options, like surgery and chemotherapy, have limitations, necessitating the development of targeted therapies. Research-driven innovation, including immunotherapies and targeted approaches, promises transformative breakthroughs. Phage display biotechnology holds promise in the pursuit of anti-cancer drugs by leveraging the unique ability of bacteriophages to present diverse antibody and peptide sequences. In this research, libraries of phages expressing scFv antibody fragments (Yamo-I) or 12-mer peptides (SUT-12) are screened to identify specific antibody that specifically bind to novel target on cancer cell and KRAS, a key molecule involved in lung cancer pathways. The selected scFv and peptides can then be further developed into therapeutic agents. Phage display technology thus represents a powerful tool in the rational design of anti-cancer drugs, offering a tailored and precise approach to combat lung cancer.

Objectives: To use phage display biotechnology approach to develop a novel treatment for lung cancer.

Progress/Findings/Results:

Cell-based biopanning of a non-immunized human scFv antibody library (Yamo-I) resulted in the isolation of several phage clones. However, after DNA sequence analysis, all these clones represented only one scFv sequence, named N11. Next the scFv was expressed in a soluble from using *E. coli* expression system and its ability to bind the appropriate cell targets was confirmed by flow cytometry analysis. Upon engineering and produced from HEK expression system as a full-length IgG1 and BiTE, N11 in either format showed interaction against a broad panel of human cancer cell lines, specifically, A549, DMS-53, MCF-7, DU145, U343 and HT-1080. Importantly, flow cytometry analysis of N11 reactivity against normal human PBMCs indicates that it does not recognize normal blood cells, which suggests a low risk of autoreactivity and provides preliminary evidence of N11 safety. CRISPR/Cas9-based library screening technique was used to identify the cell surface target

antigen. Sequence analysis of clones that didn't react with N-11 after transfected with CRISPR library indicated that the knockout gene encoded CADM-1. When a gene of CADM-1 was transfected into cell that couldn't bind to N-11, the binding was restored. Moreover, binding of N-11 to recombinant CADM-1 could be observed by ELISA. This work, therefore, may help identify novel cancer-associated molecules as well as provide effective immunotherapeutics to target malignant cells in cancer patients as well as a diagnostic antibody for certain cancers that over express CADM-1.

Conclusion: Phage display biotechnology could be used to identify novel antibody that has a potential to be used as novel therapeutics of lung cancer.

Current Output:

Rasri, N., Tabtimmai, L., Kraiya, C., Yamabhai, M., Sinthuvanich, C., Rattanasrisomporn, J., and Choowongkomon, K. (2023). Generation of a Single-Chain Variable Fragment Antibody against Feline Immunoglobulin G for Biosensor Applications. ACS Omega *8*, 27688-27696.

Challenges/Problems and Possible solutions: -

Future plan: Anti-cancer activity of clone N11 will be studied *in vitro*, based on ADCC assay, and *in vivo* using mouse model, grafted with small cell and non-small cell lung cancer cell lines. N-11 scFv-drug conjugates will be engineered and both scFv- and IgG- toxin conjugates will be used in the anti-cancer analysis. In addition, binding characteristic of the antibody to the targets will be characterized to determine binding affinity and mode of interaction.

MycoSMART: **Myco**toxin **S**trip based on **M**icro**AR**ray **T**echnology

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Project duration: 3 year, from 1 November 2021 to 31 October 2024

Current progress: 70%

Abstract:

mycoSMART has successfully strengthened the collaboration among the partners: Queen's University Belfast, Thammasat University and National Science and Technology Development Agency. The International Joint Research Center on Food Security (IJC-FOODSEC) has been officially established in July 2022. Since its launch, IJC-FOODSEC has organized numerous activities to strengthen and expand research network further both nationally and internationally throughout the stakeholders which results in many funding opportunities, staff exchanges, workshops, and conferences. In addition to the global strengthening achievements, the consortium has successfully developed and validated mycoSMART: a point-of-care microarray-based lateral flow device, with a portable reader and green sample extraction procedure, for simultaneous quantitation of five important mycotoxins (AFB1, FB1, ZEN, T-2 toxin and DON). This novel mycoSMART enables the possibility of identifying co-contaminated rice and rice-based products at the earliest possible stage, resulting in more effective mitigation measures and reduction in economics losses associated with product rejections and food waste.

Rationales/Problem statements:

Global food security is a serious threat that requires multisectoral and international partnership to urgently address. It is important to join the forces of high-caliber multidisciplinary experts and relevant stakeholders to tackle this alarming problem. Thie project was therefore set forth to establish an International Joint Research Center on Food Security (IJC-FOODSEC) to collaborate and promptly address the emerging food security problems.

Food security concerns availability, nutrition, and safety. Initially, IJC-FOODSEC highlighted food safety using mycotoxin contamination as a model research program. This

is because 60-80% of food is contaminated with mycotoxins, and 1/3 of total food loss (1.3 billion metric tons) is the result of mycotoxin contamination. The scale of mycotoxin contamination is expected to increase worldwide due to the changing climate and agricultural practices. Thus, state-of-the-art analytical techniques enabling continuous surveillance and monitoring of mycotoxins are needed.

Objectives:

Our consortium has prioritized food safety issues at its heart by conducting the following activities:

- To develop a novel point-of-care microarray-based lateral flow device with a portable reader to detect multiple mycotoxins.
- To organize events that will allow multisectoral and multidisciplinary experts to collaborate and form research networks on food security.
- To disseminate the outputs of the project to the stakeholders and public through conferences and publications.
- To strengthen and expand global collaboration on food security, prioritizing food safety.

Progress/Findings/Results:

Global Strengthening Network

From the three founding members, IJC-FOODSEC network has expanded and recognized as a hub of global consortium of food-security experts through the following activities:

Conference participation:

Workshop: 5 workshops on

- "The advancement of sample preparation and analysis for feed and food contaminations", Thailand Science Park, Thailand, 2 November 2022.
- "Developing decision support tool(s) for mitigating mycotoxins risks caused by climate change", Thailand Science Park, Thailand, 12 -13 September 2023.
- "Co-Creating Strategy for UK-Thailand Cooperation in Science, Research and Innovation" Mandarin Hotel, 9 August 2023
- "Public Dialogue on Co-Creating Strategy for UK-Thailand Cooperation in Science, Research and Innovation", Centara Grand at Central Plaza Ladprao, 2 Oct 2023.
- "High-level policy dialogue on climate resilience for the local food system", Century Park Hotel, 24 March 2023

***Conference organization*:** 3 international conferences:

- The 13th World Mycotoxin Forum, Parma, Italy, 16-18 May 2022
- The 14th World Mycotoxin Forum, Antwerp, Belgium, 9-11 October 2023
- The ASEAN-ASSET 2023: Global Summit on the Future of the Future Food, Bangkok, Thailand 14-15 November 2023

Research Progress

A multiplex point-of-care microarray-based LFIA device, with a portable electronic reader and green sample extraction procedure was successfully developed for simultaneous detection and accurate quantitation of trace levels of five important mycotoxins (AFB1, FB1, ZEN, T-2 toxin and DON) commonly found in rice. The target mycotoxins — AFB1, FB1, ZEN, T-2 toxin and DON — can simultaneously be extracted from milled rice samples using a to-be-patented in-house green solution and tested on to the microarray lateral flow strip. Within a 15-minute incubation, a microarray fluorescence image of the strip test can be captured using a portable microarray reader. Then, an intelligent and user-friendly software package was successfully developed in-house for the portable reader, data processing and estimation of the levels of each mycotoxin in the samples based on the intensity of microarray spots or signal. The developed microarray-based immunoassay

detects mycotoxins through a direct competition approach, with an in-house designed and synthesized luminescent dye conjugated to goat anti-mouse antibody employed as a fluorescence reporter.

Conclusion:

The project achieved in strengthening and expanding global research network on food security by successfully establishing IJC-FOODSEC which serves as a springboard for wider research collaboration both nationally and internationally. IJC-FOODSEC was able to deliver excellent research outputs and secure large funding from various funding agencies totaling more than 1 million euro since its official launch in July 2022. Specific to this proposal, IJC-FOODSEC has demonstrated the synergy from multidisciplinary expertise by successfully developing the novel point-of-care device enables the possibility of identifying co-contaminated rice and rice-based products, resulting in more effective mitigation measures and reduction in economics losses.

Current Output:

Publications: 2 published, 1 revised, 1 submitted, 2 in preparation

- Adunphatcharaphon, S., Christopher T. Elliott, Sooksimuang, T., Charlermroj,R., Petchkongkaew, A., Karoonuthaisiri, N. The evolution of multiplex detection of mycotoxins using immunoassay platform technologies**.** *Journal of Hazardous Materials 432*, 128706. https://doi.org/10.1016/j.jhazmat.2022.128706 (2022).
- Noppakuadrittidej, P., Charlermroj, R., Makornwattana, M., Kaew-amdee, S., Waditee-Sirisattha, R., Vilaivan, T., Praneenararat, T., & Karoonuthaisiri, N. Development of peptide nucleic acid-based bead array technology for Bacillus cereus detection. *Scientific Reports* 13. 12482. https://doi.org/10.1038/s41598-023-38877-1 (2023).
- Pichayawaytin, G., Somboonkaew, A., Jintamethasawat, R., Karoonuthaisiri, R., Sooksimuang, T., & Doljirapisit, N. A Method and Optical References for Compensating Signal Drift in a Fluorescent Microarray Reader. *Journal of the International Measurement Confederation*. (2023) (Revising)
- Kolawole, O., Thammakhet-Buranachai, C., Petchkongkaew, A., Sooksimuang, T., Elliott, C.T., Karoonuthaisiri, N. "Evaluating the Green Credentials and Performance of Deep Eutectic Solvents in the Extraction of Antibiotics and Mycotoxins in Foods" submitted to *Environmental Chemistry Letters.*

Patents: 4 patents filled

- G. Pichayawaytin et al., Light readout system for microarray spots, Thailand Patent Application No. 2301006142, Sep 2023.
- G. Pichayawaytin et al., Signal processing for improving microarray detection variation, Thailand Patent Application No. 2301006144, Sep 2023.
- T. Sooksimuang et al., 1-(n-Carboxyalkyl)-4-(7,12-dimethoxy-1,3-dioxo-4,5,14,15-tetrahydro-2H-dinaphtho [2,1-e:1',2'-g]isoindol-2-yl)pyridin-1-ium bromide as a reporter molecule for biomolecule, Thailand Patent Application No. 2301006216, Sep 2023.
- T. Sooksimuang et al., Derivatives of 3,4-dicyano-1,2,5,6-tetrahydrodibenzo[c,g]phenanthrene bearing poly(ethylene glycol) methyl ether as a reporting molecule for biomolecule, Thailand Patent Application No. 2301006221, Sep 2023.

Prototypes: 1 reader prototype

Challenges/Problems and Possible solutions:

- This project started during the COVID-19 period which hindered speed of the research progress at the beginning.

- Every contract requires lengthy and complicated process.

Future plan:

The consortium from this project continues to expand research network to secure larger funding and conduct important research problems with global impacts. In term of mycoSMART system, several companies have shown interests to license or collaborate. The technology platform of this system has been applied for other applications such as allergy detection and will be applied for other purposes as well.

Nanoparticle-Mediated Metabolic Reprogramming in Dendritic Cells and Macrophages for Immunotherapy of Systemic Lupus Erythematosus and Sepsis

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 80%

Abstract:

This project combined nanotechnology with immunotherapy to modulate dendritic cell (DC) and macrophage functions by reprogramming their metabolism for the treatment of systemic lupus erythematosus (SLE) and sepsis. We developed 2 nanoparticle prototypes for dendritic cell (DC)- and macrophage-targeted therapy. First, we developed a new immunosuppressive nanoparticle containing a biodegradable PDMAEMA-PLGA copolymer and dexamethasone for target-oriented delivery to dendritic cells (DCs) in situ and applied this innovation to a preclinical study using a lupus-prone mouse model. Second, we loaded BAM15, a mitochondrial uncoupling agent, into polymeric nanoparticles and demonstrated the superior efficacy of the BAM15 nano-delivery system. We also provided support in a preclinical study using a sepsis mouse model. At present, we have published 3 international publications (two are in the Tier 1 journal and one is the Q1 journal). We hope that our establishment in academic and medical innovations will be a future medicine in Thailand.

Rationales/Problem statements:

Dendritic cells (DCs) and macrophages play an important role in the initiation and progression of inflammatory-mediated diseases, including sepsis and systemic lupus erythematosus (SLE). Immunometabolism has emerged as a major mechanism that is central to immune activation and regulation. Therefore, metabolic reprogramming of these innate immune cells toward a proper direction will provide therapeutic benefits in inflammatory-mediated diseases. To harness the recent emerging knowledge regarding the metabolic control and biological functions of DCs and macrophages, we combined nanotechnology with immunotherapy to specifically deliver drugs and/or molecules to modulate DC and macrophage metabolism, which help to reduce off-target toxicity and enhance the treatment potential in sepsis and SLE.

Objectives:

1) To establish a new formulation of DC- and macrophage-targeting nanoparticles to reprogram their metabolism in vitro and in situ.
2) To apply our approaches in vitro and in the preclinical studies using mouse models of sepsis and lupus.

Progress/Findings/Results:

We developed a new immunosuppressive nanoparticle containing a biodegradable PDMAEMA-PLGA copolymer loaded with dexamethasone (Dex-NP) for targeted delivery to DCs in situ. We used dexamethasone as a model, and our preexisting data also showed that dexamethasone can modulate lipid metabolism in DCs. Dex-NP therapy potentially alleviated lupus disease in *Fcgr2b*$^{-/-}$ mice by mediating Foxp3^{+} Treg expansion in an antigen-specific manner. Furthermore, PDMAEMA-PLGA NP may be a versatile platform for DC-

targeted therapy to induce antigen-specific immune tolerance to unwanted immune responses that occur in autoimmune disease, allergy, and transplant rejection.

In parallel, we targeted mitochondrial energy in macrophages by using a polymeric nanoparticle loaded with BAM15, a mitochondrial uncoupling agent, loaded (BAM nano). The BAM15 nanoparticles showed specific effects on the inflammatory response of macrophages, but not neutrophils, and the nanoparticles were also actively captured by splenic and liver macrophages in vivo. Administration of BAM15 nano attenuated the severity of sepsis in LPS-induced sepsis mice. In addition, BAM15 nano potentially alleviated LPS-induced liver injury by reducing liver inflammation in the sepsis mouse model. Our findings substantiate the superior efficacy of macrophage-targeted therapy using the BAM15 nano-delivery system and provide further support for clinical development as a potential therapy for severe inflammatory diseases.

To date, we have developed 2 formulations of nanoparticles and have published 3 international publications (two are in the Tier 1 journal and 1 is in the Q1 journal). In addition, two manuscripts are in preparation, which we plan to submit to the Tier 1 journal by December, 2023.

Conclusion:

In clinical translation, our results support the possibility of immune modulation in some conditions through the specific blockage of the limited types of immune cells. While general blockage of metabolic pathway in all cells can cause adverse effects, the targeted drug delivery to DCs and macrophages helps reduce off-target side effects. Our study demonstrated the successful reprograming of metabolism in DCs and macrophages in the mouse model of sepsis and lupus using a polymeric nanoparticle platform. However, several further adaptations to the nanoparticles are still needed to improve the selectivity and specificity. For future personalized medicine, biomarkers that demonstrate hyperfunction of DCs and macrophages could be a candidate target for nanoparticle delivery. Thus, more studies are warranted.

Current Output:

1) 2 formulations of drug-loaded nanoparticles
2) 3 international publications (2 in the Tier 1 journal and 1 in the Q1 journal).
3) 2 manuscripts are in preparation which we plan to submit to the Tier 1 journal by December, 2023.

Challenges/Problems and Possible solutions:

We lack a GMP facility to develop the nanoparticles in GMP grade for testing their toxicity in cells and preclinical study.

Future plan:

We plan to seek international collaboration for the GMP facility to develop our nanoparticles in GMP grade and test their toxicity in cells and animals. Furthermore, we will also apply our nanoparticle platform to other immune-related diseases such as cancer.

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ด้าน Global Partnerships (Biotechnology)

Functions and Mechanisms of Calmodulin-binding Transcription Activator (CAMTA) under Salt Stress in Rice Revealed Using RNA-Seq Integrated with ChIP-Seq

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 73%

Abstract:

Calmodulin-binding transcription activator (CAMTA) is one of the CaM-binding proteins that act as a transcription factor. Analysis of *CAMTA* gene family in *Oryza sativa* L. var. Kitaake annotated 7 *CAMTA*s based on their sequence similarity to known *CAMTA* genes in other plant species. Phylogenetic analysis of *CAMTA*s revealed that each of the rice *CAMTA*s had corresponding ortholog with *CAMTA*s from maize. All *CAMTA*s were significantly up-regulated at 3h after salt treatment in both shoot and root or at least in one of them. To investigate their functions, CRISPR/Cas9 knockout rice plants of *OskCAMTA1*, *OskCAMTA2*, and *OskCAMTA6* were successfully generated. *Oskcamta1* and *oskcamta2* knockout rice seedlings exhibited higher salt stress sensitivity than wild type. Transcriptome profiling of the *Oskcamta1* knockout rice under salt stress was conducted. Finally, the recombinant HALO-CAMTA1 protein was produced and purified to be used for DAP-Seq in order to determine CAMTA1-binding sequences in the rice genome.

Rationales/Problem statements:

Previously, our group has screened rice cDNA expression library and identified an OsCAMTA as one of the CaM-binding proteins. In Arabidopsis, CAMTAs involve in environmental stress and hormone responses. The knockout *atcamta1* showed a higher sensitivity to drought, indicating its positive function in drought response. *At*CAMTA3 acted as a negative regulator of salt tolerance by directly repressing the expression of salt-responsive genes. There are reports on *CAMTA* genes in other plants e.g. legume, maize, poplar and soybean in abiotic and biotic stress response. In rice, a *CAMTA* gene in the qSCT1 locus was found associated with cold tolerance. *Os*CAMTA5 was reported to suppress defense responses to pathogens. In this study, we performed sequence-based analysis of *CAMTA* gene family in Kitaake rice. Gene structure, promoter elements, conserved domains and their expression under salt stress were analyzed. We generated *oscamta* knockout rice lines by CRISPR/Cas9 system, which will further support functional characterization of some selected *OsCAMTA* genes in the mechanisms of salt stress responses.

Objectives:

1. Identify CAMTA protein that plays important role in the response to salt stress in rice
2. Determine CAMTA-binding sequences in the rice genome and identify target genes at a genome-wide scale
3. Build a gene regulatory network in the response to salt stress mediated by CAMTA

Progress/Findings/Results:

Annotation of rice *CAMTA* genes Seven *CAMTA* genes found in Kitaake rice showed similar exon-intron pattern indicating a conservation of their genomic structure. Several *cis*-elements were related to phytohormone involving in abiotic stress response. All encoded proteins contained the conserved domains found in other plant species. Their location was predicted to be the nucleus. By phylogenetic analysis, sixty-two CAMTA proteins were clustered into six subfamilies. *Os*kCAMTAs falling into 3 subfamilies had corresponding orthologs in maize, which responded to abiotic stress including cold, drought and salt stresses, suggesting that *Os*kCAMTAs involve in abiotic stress.

***CAMTA* genes expression under salt stress** All *CAMTA*s were significantly up-regulated at 3h after salt stress in both shoot and root or at least in one of them. In root, all genes were also up-regulated at 6h. These results indicated that *CAMTA*s were rapidly responsive to salt stress at the transcriptional level.

Generation of *oscamta* knockouts using CRISPR/Cas9 system Seven constructs for knockout of each *CAMTA* containing three target adaptors were generated and introduced into Kitaake rice via *Agrobacterium*-mediated transformation. Homozygous knockout rice plants of *OskCAMTA1*, *OskCAMTA2*, and *OskCAMTA6* were generated. Verified by PCR, *Cas9*-free T_2 plants were obtained.

Phenotyping of the *oscamta* CRISPR/Cas9 knockouts Based on shoot fresh weight and dry weight, and root dry weight, 21-day old *oskcamta1* knockout rice seedlings were more sensitive to salt stress (150 mM NaCl) than wild type. *Oskcamta2* knockout rice seedlings also exhibited higher sensitivity to salt stress based on the chlorophyll content measured by SPAD index and relative water content. Additionally, *oskcamta2* and *oskcamta6* knockout rice seedlings appeared to have lower root growth than wild type even when grown under normal conditions.

Transcriptome profiling of the *oskcamta1* knockout rice Four-week old seedlings of *oskcamta1* knockout rice and wild type were treated with salt stress (150 mM NaCl) for 3 h. Leaf and roots tissues were used for RNA isolation and DNA library preparation. Pair-end sequencing was carried out by the Illumina genome analyzer. Sequence reads were mapped to MSU rice genome by hisat2. The mapped reads were counted by hiseq and differentially expressed genes (DEGs) were identified by DESeq2. The list of DEGs is being examined.

Production and purification of recombinant HALO-CAMTA1 protein for DAP-Seq pIX-HALO-CAMTA1 was constructed and used for transforming *E.coli* strain Bl21(DE3). Recombinant protein of expected size (134 kDa) was observed both in soluble fraction and in inclusion bodies. The crude extract was purified using Magne® Beads or HisTrap HP.

Conclusion:

Seven *CAMTA* genes in *Oryza sativa* L. var. Kitaake were annotated. All *OskCAMTA* genes were significantly up-regulated at 3h after salt treatment in rice shoot and/or root. Here, we generated CRISPR/Cas9 knockout rice of *Oskcamta1* and *oskcamta2* and showed that they exhibited higher salt stress sensitivity when compared with wild type rice. Transcriptome profiling of the *Oskcamta1* knockout rice under salt stress was performed and its analysis is ongoing. To determine CAMTA1-binding sequences in the rice genome, the recombinant HALO-CAMTA1 protein was produced and DAP-Seq will be performed using this protein.

Current Output: -

Challenges/Problems and Possible solutions: -

Future plan:

The list of differentially expressed genes (DEGs) identified from RNA-Seq will be examined to interpret the roles of DEGs. HALO-CAMTA1 protein will be used to perform DAP-seq. Information from the list of DEGs and the CAMTA1-binding sequences will be integrated to build a gene regulatory network in the response to salt stress mediated by CAMTA in rice.

Development of the Floral Injection Technique for Delivering the CRISPR/cas9 Cassette to Edit Genome in Rice

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Project duration: 2 years, from 1 November 2021 to 31 October 2023
Current progress: 60%

Abstracts (Maximum 150 words):
The development of the floral injection method for *in planta* transformation in rice was accomplished via *Agrobacterium*-mediated transformation employing a simple inoculum formula. The project successfully transferred the T-DNA of the CRISPR/Cas9 constructs from an intron-based single transcript unit CRISPR system, into the rice varieties RD47 and Phitsanulok 2 using the floral injection technique, confirming successful transfection. The presence of T-DNA was confirmed by examining segments of the hygromycin resistance gene and the 35S promoter within it. More than 50 T1 plants (either *Nal1* or *SWEET*-EBE targets) were obtained. Although T-DNA was detected in the T1 plants, examining the nucleotide sequences of the targeted gRNA regions in 16 T-DNA-positive T1 plants (5 and 11plants for *Nal1* and *SWEET*-EBE targets, respectively) revealed no indel mutations in any of the examined plants.

Rationales/Problem statements:
Plant transformation techniques have been developed successfully and applied to a wide variety of plants, including important crops like rice. These methods involve using vectors such as *Agrobacterium* (Agrobacterium-mediated transformation) or particle bombardment (biolistics). However, most of these techniques require tissue culture methods. Tissue culture is a challenging step that demands expertise, incurs high costs, and consumes considerable time to obtain transformed plants. Additionally, there is a notable risk of somaclonal variation. Presently, plant transformation techniques are undergoing development, introducing a novel method known as in planta transformation. This approach eliminates the need for tissue co-cultivation in various plant species, simplifying DNA transfer into plants. It offers ease, cost-effectiveness, and faster production of transformed plants compared to traditional tissue culture methods. The research team is interested in developing in planta transformation techniques for rice, specifically focusing on transitioning from the Floral dip technique to the Floral injection technique.

Objectives:
To develop the *in planta* transformation technique utilizing a novel floral injection method for transferring the CRISPR/Cas9 cassette to edit the rice genome using the CRISPR/Cas9 system.

Progress/Findings/Results:
The project conducted floral injection on both rice varieties RD47 and Phitsanulok2 using *Agrobacterium* clones EHA105-pGEL081Nal1U6, EHA105-pGEL085Nal1U6, EHA105-pGEL081SW11-RA, and EHA105-pGEL085SW11-RA to prepare the inoculum formula 2 without dilution, incubated at 25°C. After 48 hours, each process was applied to at least 500 flowers (located in the middle of the inflorescence). Results indicated successful seed setting. Nevertheless, T1 seeds obtained via floral injection frequently suffer from fungal infections, leading to imperfect seeds and a high likelihood of seedling mortality when planted directly

in soil. Consequently, the method was modified to cultivate seeds on MS medium post-bleaching and disinfection to eradicate fungi and promote seed germination strength before transplantation into soil. This alteration has resulted in T1 plants with improved survival rates. However, this additional step has caused a delay of 3-4 weeks in the test planting process. Initially, bulk PCR analysis was conducted for T1 screening, followed by individual examination of T1 plants from the positive bulk samples. After examining the hygromycin resistance gene and the 35S promoter, the project identified 51 T1 plants that tested positive for T-DNA. Subsequently, the nucleotide sequences within the gRNA areas of the first 16 T1 plants were scrutinized. Among these, the nucleotide sequences of the gRNA regions of the *Nal1* gene and the *SWEET11* promoter in 5 and 11 plants, respectively, were specifically assessed. However, upon examining the nucleotide sequences, no alterations were observed when compared to the normal nucleotide sequences.

Conclusion:

The project was able to introduce CRISPR/Cas9 T-DNA of the Intron-based single transcript unit CRISPR system into rice varieties RD47 and Phitsanulok 2 using the floral injection method. More than 50 screened T1 plants showed positive T-DNA results. However, upon analyzing the gRNA target sequence in 16 of these T1 plants, no plants were found to exhibit indel mutations, despite the initial positive T-DNA confirmation.

Current Output:

The optimal condition for *in planta* rice transformation technique using floral injection.

Challenges/Problems and Possible solutions:

Despite successfully developing the floral injection technique to transfer CRISPR/Cas9 T-DNA into experimental rice varieties, it did not induce mutations in the target DNA region in T1 plants. We attempted using a new CRISPR/Cas9 construct system, known for its ability to induce mutations in rice cells, but were unsuccessful. Consequently, the project did not meet the planned goals. Unexpectedly, the CRISPR/Cas9 constructs failed to induce mutations in the targeted genome regions, despite their previous success in inducing indel mutations in rice cells. We will conduct examinations on all remaining T1 and T2 plants and explore indel mutations through callus transformation.

Future plan:

The project will examine the remaining T1 plants and evaluate the T2 plants derived from T1 plants with confirmed T-DNA presence to assess both the stability of T-DNA transmission and mutations in the targeted gRNA regions. Furthermore, T-DNA transfer via callus will be conducted to examine the functionality of the CRISPR/Cas9 construct, determining its capability to induce indel mutations.

Identification and Functional Characterization of Circular RNA in Shrimp upon White Spot Syndrome Virus Infection Using Omics Technology

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Project duration: 2 years, from 1 November 2021 to 31 October 2023
Current progress: 100%

Abstract:
On the contrary to other organisms, an information on circular RNAs (circRNAs) in shrimp was limited due to the fact that these molecules have been studied to participate in various biological mechanisms. This project was thus of interest to identify and functionally characterize white spot syndrome virus (WSSV)-responsive circRNAs, which are originated from host's and WSSV's genetic materials. Furthermore, the structural and chemical characteristics have been validated to conform their signature and found to be expressed relatively to their linear parental genes. One of functional aspects of circRNAs, which is microRNA (miRNA) sponge, has been discerned, interacting with WSSV-responsive miRNAs. Moreover, viral circRNAs derived from WSSV transcripts have been investigated and one circRNA, circVP28 generated from *VP28* mRNA, is capable of being a template for protein translation, introducing a circVP28-encoded protein (ceVP28) and a novel antiviral mechanism able to competitively block a host's receptor required for the viral entry.

Rationales/Problem statements:
Shrimp production has been perturbed by many infectious diseases resulted from pathogens wherein WSSV is one of eradicative virus affecting many shrimp-farming areas, especially in Thailand. Many approaches to coping the spreading and mortality upon infection have been strategized. For instance, immunostimulants, probiotics, RNAi techniques have shown to improve the mortality of shrimp during WSSV infection. Nevertheless, an insight into the underrepresented topics like the roles of circRNAs in shrimp in response to viral pervasion was inadequate despite being clarified on other organisms and found to possess many pivotal roles in numeral biological processes.

Objectives: Identify circRNAs in WSSV-infected shrimp using omics technology

- Characterize the putative roles of WSSV-responsive circRNAs upon WSSV infection
- Functionally disclose the circRNAs capable of facilitating or protecting shrimp from WSSV invasion.

Progress/Findings/Results:

- CircRNAs have been acknowledged shrimp.
- A total of 290 differentially expressed circRNAs (DECs) upon WSSV infection were discerned.
- One functional roles of circRNAs has been predicted and displayed the new targets, which could be employed to strategize to modulate the intricate control of immune-related genes through miRNA sponge.
- Four viral circRNAs derived from WSSV transcripts were identified and validated to conform the circRNA's characteristics.
- CircVP28 has a capability to be employed as a template for protein synthesis, thus

generating a novel truncated protein that had never been recognized beforehand.

- CircVP28-encoded protein, so-called ceVP28, shares the same binding partner of a WSSV's structural protein, VP28, obliged for the attachment of the virus to the host cell.
- Co-administration of WSSV and ceVP28 was able to alleviate the mortality during WSSV challenge.
- This finding has unveiled a novel self-defense mechanism employed by host through blocking viral entry capable of protecting or mitigating uninfected cells.

Conclusion:

- This study has firstly introduced a solid evidence that circRNAs do exist as the same as other eukaryotic organisms.
- An acquisition of viral circRNA and its translated protein has revealed an unprecedented process involved in an antiviral system in shrimp.

Current Output:

Submitted manuscript:

Limkul, S., Phiwthong, T., Wanvimonsuk, S., Seabkongseng, T., Aunkam, P., Jaree, P., Luangtrakul, W., Mahanil, K., Teamtisong, K., Tittabutr, P., Teaumroong, N., Sarnow, P., Wang, H.C., Somboonwiwat, K., & Boonchuen, P. (2023). Viral circular RNA-encoded protein, ceVP28, divulges an unprecedented antiviral response in invertebrate (Submitted).

Published articles:

Limkul, S., Phiwthong, T., Massu, A., Boonanuntanasarn, S., Teaumroong, N., Somboonwiwat, K., & Boonchuen, P. (2023). Transcriptome-based insights into the regulatory role of immune-responsive circular RNAs in Litopanaeus vannamei upon WSSV infection. *Fish & Shellfish Immunology*, *132*, 108499. doi: https://doi.org/10.1016/j.fsi.2022.108499

Sriphuttha, C., Limkul, S., Pongsetkul, J., Phiwthong, T., Massu, A., Sumniangyen, N., . . . Boonchuen, P. (2023). Effect of fed dietary yeast (Rhodotorula paludigena CM33) on shrimp growth, gene expression, intestinal microbial, disease resistance, and meat composition of Litopenaeus vannamei. *Developmental & Comparative Immunology*, *147*, 104896. doi: https://doi.org/10.1016/j.dci.2023.104896

Challenges/Problems and Possible solutions:

- An unavailable cell-line suitable for representing shrimp is a major challenge for overexpressing or silencing circRNAs *in vivo*.

Future plan:

An effective delivery system of circRNA precursors and circRNA-generating schemes are needed in order to scrutinize the participation of these circRNAs in shrimp's immunity responsible for protecting shrimp from pathogenic infections. Therefore, these approaches will be studied further to clarify the roles these enigmatic molecules in the innate immune system. Furthermore, these tools could be employed further as the specific features of circRNAs have been exploited such as an alternative form of mRNA vaccines, thus introducing new stable methods that could immunize shrimp prior to the infection capable of alleviating the mortality upon the invasion of bacterial and viral pathogens.

Investigation of the Host-gut Microbial Functional Relationship Using the Black Tiger Shrimp as a Model: From Community to Single Cell Microbiome Analysis

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Project duration: 3 years, 1 November 2021 to 31 October 2024

Current progress: 70%

Abstract:

In recent years, advancements in sequencing and metabolite detection have enabled multi-omic to understand roles microbial communities and potential applications to improve shrimp health. Our focus is on developing a single-cell approach for shrimp gut microbiota analysis, combining it with -omic methods to fill functional knowledge gaps. Here, we have established high-quality bacterial genome as reference database, developed a shrimp digesta collection method for -omics analysis, completed single-cell transcriptomic analysis for shrimp hemocytes upon exposure to WSSV. Moreover, we also explored shrimp gut-environment interactions and to investigate the impact of starvation on shrimp gut microbiome at a single-cell level. Our tangible outputs include 3 peer-review publications, 1 editorial article, 4 presentations at international conference, and capacity building by mentoring master's and postdoctoral scholars, offering hands-on research experience. Our team also engaged in a symposium on aquaculture, fostering partnerships for industry collaboration and practical application of research findings.

Rationales/Problem statements:

The comprehensive understanding of the intricate relationship between the black tiger shrimp and its gut microbiome is still in its infancy, particularly regarding how specific gut bacteria influence shrimp health and growth. This research fills knowledge gap by elucidating how specific bacterial groups within the gut microbiota contribute to the shrimp's well-being, growth, and health. The project aims to integrate various disciplines, such as molecular biology, microbiology, and systems biology, to pioneer innovative methodologies for analyzing the microbiome at a single-cell resolution. Understanding host-gut relationships at both the community and single-cell levels could pave the way for tailored strategies to optimize the selection of beneficial bacterial consortia, potentially enhancing shrimp health and growth performance. This knowledge will lead to practical applications, contributing significantly to the advancement of shrimp aquaculture practices and overall aquatic health management.

Objectives:

Aim 1. To develop single-cell microbiome for functional analysis in gut associated-bacteria using defined culture system.

Aim 2. To elucidate functions of individual member of the shrimp gut microbiota in response to feed additives by using the developed single-cell genomic approach.

Progress/Findings/Results:

- Establishment of high-quality bacterial genome data of the selected bacterial isolates as our reference database. The selected bacterial candidates are being used as our “defined” population for metatranscriptomics and metagenomics analysis.
- Development of shrimp digesta collection method. To obtain a higher proportion of DNA or RNA from bacteria than from the host shrimp, we aimed to collect “digesta” samples, which are mainly matrices in the shrimp intestines for our -omics analysis in addition to a standard collection of a whole intestine.
- Development of single cell transcriptomic analysis method, in which conditions for the single cell separation were successfully developed. To further apply the developed approach, we set up an animal trial where shrimp were exposed to white spot syndrome virus (WSSV) as a representative of infected shrimp. Hemocytes were collected from the infected shrimp and healthy shrimp. In-depth analysis of single-cell RNA sequencing data revealed that the control shrimp hemocytes consisted of four distinct sub-populations, whereas the hemocytes of the WSSV-infected groups exhibited three sub-populations.
- Determination of interaction between environmental factors and the gut of shrimp. We conducted a study examining how rearing environments, including water and sediments, influenced shrimp gut diversity, and vice versa, in field environments. Samples were collected from two distinct ponds. Our results indicate that the gut of shrimp primarily interacts with the surrounding water rather than the sediment
- A single cell transcriptomic analysis of shrimp under starvation to elucidate cellular heterogeneity and stress-responsive gene networks. Particularly, the gut microbiome plays a crucial role in an animal's health and growth. Starvation can alter microbial dynamics within the gut. The experimental trial and tissue collection have been completed. Currently, tissues are subjected to single-cell RNAseq, bulk RNAseq and histological analyses, along with microbial diversity analysis in intestine of shrimp under starvation.

Conclusion:

Our research efforts have yielded significant progress in understanding the black tiger shrimp's gut microbiota and its pivotal role in shrimp health and environmental interactions. Firstly, we have established a high-quality bacterial genome database comprising selected bacterial isolates. These isolates serve as our reference for metatranscriptomics and metagenomics analysis, crucial in unraveling microbial functionality. Additionally, the development of a shrimp digesta collection method enhances our ability to obtain DNA/RNA predominantly from bacteria in shrimp intestines, vital for -omics analysis. To study at a single-cell transcriptomic level, the approach for tissue isolation has been successfully developed. We applied our scRNA approach to investigate how host shrimp responses to WSSV and under starvation conditions. Furthermore, our study on environmental factors' interaction with the shrimp gut microbiome demonstrates a strong correlation between gut microbiota and water environments, influencing shrimp gut diversity.

Current Output:

3 publications, 4 presentation at international conferences, 1 mini-symposium, Thai Young Generation Dialogue, 1 postdoctoral fellow, 2 MS students

Challenges/Problems and Possible solutions:

Future plan:

Finalization of manuscript drafts on scRNAseq analysis of shrimp under WSSV exposure and under starvation, effects of feed additive on host-gut microbiome, metatranscriptomics of bacteria and validation our single-cell bacterial method.

Integration of Fundamental Knowledge on Shrimp Digestive Tract: Structure and Function

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 64%

Abstract:
The shrimp aquaculture industry is an important part of Thailand's economic and social systems and plays a vital role in global food security and nutrition. This research project aims to create a body of fundamental knowledge of the shrimp digestive system to apply the knowledge to solve the current and potential epidemic problems in shrimp aquaculture. The project covers the study of histology and cytology of the gastrointestinal tract, functions, hormonal regulations, and gut microbiota. Moreover, the effects of critical internal and external factors, i.e., molting, hormones, water quality, pathogens, and feed formulas, on the digestive system are investigated. In addition, the project aims to study compounds and hormones that can stimulate shrimp feeding behavior to develop an effective shrimp diet.

Rationales/Problem statements:
Thailand was the world's top shrimp exporter until a disease outbreak caused production to decrease in 2011. Nowadays, almost all the significant shrimp pathogens attack the shrimp digestive system, causing death and slow growth. However, the understanding of the digestive system in shrimp is still unsystematic and insufficient to comprehend the mechanism of diseases and evaluate digestive health, leading to unresolved issues. Moreover, Thailand is currently facing issues with illegal, unreported, and unregulated fishing, as well as overfishing. As a response, the government has implemented a policy to reduce the use of fishmeal in shrimp feed. Therefore, the shrimp feed industry uses alternative protein sources like soybean meal to modify formulas. However, the effects of modified shrimp diets on digestive function and health are inconclusive.

Objectives:
This research project aims to create a body of fundamental knowledge of the shrimp digestive system to apply the knowledge to solve the current and potential epidemic problems in shrimp aquaculture. The project covers the study of histology and cytology of the gastrointestinal tract, functions, hormonal regulations, and gut microbiota. Moreover, the effects of critical internal and external factors, i.e., molting, water quality, pathogens, and feed formulas, on the digestive system are investigated. In addition, the project aims to study compounds and hormones that can stimulate shrimp feeding behavior to develop an effective shrimp diet.

Progress/Findings/Results:
The three-dimensional micro-computerized tomography of the posterior stomach (PS)-hepatopancreas (HP)-midgut (MG) structural complex was revealed. A conceptual cellular

organization of HP was proposed with the functions of specific cells. Differential gene and protein expressions in each organ of shrimp at a specific age were also studied by next-generation sequencing and proteomic analysis. The effect of soybean meal-supplemented feed on fish meal feed was also examined. The impact of a protein source is more pronounced in the 2 g shrimp than in the 5 g shrimp. The gut passage (transit) time (GPT) and rate (GPR), which refer to the timing and velocity of ingesta transportation after feeding to defecation along the digestive tract, were determined. These parameters could reflect the ability of digestion and absorption efficiencies and are expected as indicators of gut performance. We also investigated the effect of EHP infection on histopathology and the activities of digestive enzymes. EHP infection caused induction of lipase activity but inhibited trypsin and amylase activities in the digestive tract of the intermolt-EHP infected shrimp continuously from 4 weeks to 8 weeks of investigation. Moreover, decreased lipid droplet accumulation in the HP of EHP-infected shrimp was found in late infection. The result suggested that EHP causes a disturbance in lipid metabolism in the HP, lowers digestive enzyme activity, and reduces the ability to digest food. Moreover, we found that 5-aminolaevulinic acid (5-ALA), a non-protein amino acid known to enhance ATP production in the cell, could reduce the mortality, increase the biomass of EHP-infected shrimp, and improve hepatopancreatic functions.

We also studied the role of neuropeptide F (NPF), which is known to control metabolism and feeding, on nutritional accumulation during ovarian maturation and feeding. Our result suggested a novel function of short NPF in ovarian development; how it regulates this process, particularly by promoting the feeding and uptaking energy and nutrients, is being studied. In addition, the attractability of krill meal extract (KME) was also studied. According to the results of the proteomic study of KME fractions, the candidate proteins acquired from proteomic lists were selected for evaluation in an attractability assay. We also showed that KME- and astaxanthin-enriched diets could stimulate the shrimp's immune system.

In addition, we investigated different microbiomes between the high nitrite and control “low” nitrite experiments. Principle component analysis reveals that CG and HN groups had similar bacterial profiles at the beginning of the culture but had greater diverged bacterial profiles from Week 4 to Week 7. Our results suggested that changes in intestinal bacterial compositions from early (Week 2) to later (Week 6) stages of shrimp culture under optimally low nitrite levels. However, higher nitrite levels might limit changes in intestinal bacterial compositions that would otherwise be developed with shrimp culture age. In addition, we investigated microbial dynamics of water in an outdoor HDPE-lined shrimp pond with no water discharge to assess the pond water characteristics and associated microbiomes of the pond water that may reflect on the intestinal shrimp microbiomes.

Conclusion:

This knowledge may explain the functions and mechanism of how shrimp direct feed particles toward the hepatopancreas and the pathophysiology of EHP infection that enters these organs. The gut passage time and rate could reflect the ability of digestion and absorption efficiencies and are expected to be indicators of gut performance. In addition, the effects of critical internal and external factors, i.e., molting, water quality, EHP, and feed formulas, on the digestive system were pointed out. Positive impacts of feed additives on gut health and immunity, including 5-aminolaevulinic acid, krill meal extract, astaxanthin, and neuropeptide F, were shown.

Current Output:

Publications in Tier1/Q1-ranked journals – 8 publications
Graduate student – 4 Ph.D. students and 2 M.Sc. students
International training – 2 workshops

Research network – Mahidol University, BIOTEC (NSTDA), Rajamangala University of Technology Tawan-ok
International collaboration - Skretting ARC, Norway

Challenges/Problems and Possible solutions: -

Future plan:

As of now, we have been able to carry out almost all of the research activities as per our plan. We have around one year remaining to complete the project. Our plan is to organize a meeting in 2024 to share the knowledge gained from the research with the research community as well as the aquaculture industry.

Roles of Eicosanoid Biosynthesis and Lipid Metabolic Pathways in Response to Gastrointestinal Tract Infections in *Penaeus vannamei*

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 70%

Abstract:

The gastrointestinal tract of Pacific white shrimp *Penaeus vannamei* infected with *Vibrio parahaemolyticus* isolate 5HP (VP_{AHPND}) were examined for changes in the eicosanoid biosynthesis and lipid metabolic pathways. VP_{AHPND} infection increased the levels of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$), *cyclooxygenase*, *prostaglandin E synthase 1* (*PGES1*), and *PGES2* transcripts in hepatopancreases and the levels of prostaglandin E_2, $PGF_{2\alpha}$, 15-deoxy prostaglandin J_2, and *prostaglandin F synthase* transcripts in intestines. VP_{AHPND} infection also affected shrimp lipid metabolic pathway as levels of oleic acid and *stearoyl co-A decarboxylase* decreased in the hepatopancreases of VP_{AHPND}-infected shrimp. In contrast, levels of free fatty acids, *acetyl CoA carboxylase*, and *fatty acid synthase* transcripts increased in intestines of VP_{AHPND}-infected shrimp when compared to those of the control shrimp. These findings indicate that VP_{AHPND} infection not only affected the eicosanoid biosynthesis and lipid metabolic pathway in shrimp gastrointestinal tract but can be used as biological markers for future newly emerging diseases.

Rationales/Problem statements:

Outbreaks of newly emerging disease in shrimp industry stemmed from intensive shrimp farming to ramp up the production yields. These diseases include *Enterocytozoon hepatopenaei* (EHP), acute hepatopancreatic necrosis syndrome (AHPND), and white feces syndrome (WFS). Although several omic technologies have been employed to examine these diseases [1–10], lipidomic analysis have rarely been included. In particular, the analysis of fatty acid derivatives called eicosanoids, which are part of the immune response to pathogenic infection and inflammation, have not been investigated in crustaceans [11–13]. Here we propose to examine the eicosanoid biosynthesis and lipid metabolic pathways in the gastrointestinal tracts of shrimp with EHP, VP_{AHPND}, and WFS. By understanding the production and utilization of lipids and lipid derivatives at the transcriptomic and metabolic levels during pathogenic infection, we may be able to provide alternative strategies for the characterization and treatment of newly emerging diseases in the future.

Objectives:

1. To establish the roles of eicosanoid biosynthesis pathway in response to pathogenic infection in shrimp infected with AHPND, EHP, and WFD.
2. To monitor changes in the lipid metabolic pathway in shrimp infected with AHPND,

EHP, and WFD.

3. To obtain the metabolic and transcriptomic profiles from eicosanoid biosynthesis and lipid metabolic pathways that are unique to each disease, which can serve as references to distinguish different pathogenic infection in shrimp GI tract in the future.

Progress/Findings/Results:

Shrimp with acute hepatopancreatic necrosis disease (AHPND) was obtained by infecting the *P. vannamei* with *Vibrio parahaemolyticus* isolate 5HP (VP_{AHPND}) at the final concentration of 10^4 CFU/mL. Hepatopancreases, stomachs, and intestines of the control and VP_{AHPND}-infected shrimp were harvested at 24-hour post-infection. As the infection mechanism of VP_{AHPND} includes colonization in shrimp stomachs and secretion of Pir-like toxins into hepatopancreases, we hypothesize that VP_{AHPND} infection alters both the eicosanoid biosynthesis and lipid metabolic pathways in shrimp gastrointestinal tract. Changes in the eicosanoid biosynthesis pathway were monitored using ultra-high performance liquid chromatography tandem mass spectrometry (UHPLC-HRMS/MS), enzyme immunoassays, and quantitative real-time PCR (qPCR) analysis. VP_{AHPND} infection suppressed the transcription levels of *cytosolic phospholipase A2* (*cPLA2*) along with the levels of (±)15-hydroxyeicosapentaenoic acid (±)15-HEPE) and (±)18-HEPE in shrimp stomachs. In hepatopancreases, however, the levels of $PGF_{2\alpha}$ increased along with the upregulation of *cyclooxygenase*, *prostaglandin E synthase 1* (*PGES1*), and *PGES2* transcripts in VP_{AHPND}-infected shrimp, suggesting that the secretion of Pir-like toxin induced the pro-inflammatory pathway in this organ. Additionally, VP_{AHPND} infection suppressed the production of anti-inflammatory signaling molecules, including (±)5-HEPE, (±)5-hydroxyeicosatetraenoic acid (±)5-HETE), (±)9-HETE, and (±)11-HETE in shrimp hepatopancreases. Lastly, VP_{AHPND} infection increased the transcription levels of *prostaglandin F synthase* and the levels of $PGF_{2\alpha}$, prostaglandin E_2, and 15-deoxy prostaglandin J_2 in shrimp intestines. The reduction of (±)5-HETE levels further supports our findings that the pro-inflammatory response was activated in the intestines of VP_{AHPND}-infected shrimp.

Lipidomic and transcriptional analyses of VP_{AHPND}-infected shrimp revealed that the lipid metabolic pathway in shrimp gastrointestinal tract was altered as shown by increasing levels of triacylglycerol (TAG) and diacylglycerol (DAG) in shrimp stomach, suggesting a surge in energy utilization due to the propagation of VP_{AHPND}. Gas chromatography-flame ionization detection (GC-FID) analysis also revealed that the stomachs of VP_{AHPND}-infected shrimp had higher levels of C18:1n-9, C18:2n-6, and C18:3n-3, but lower levels of C18:0, C20:5n-3, and C22:6n-3 than those of the control shrimp. In shrimp hepatopancreases, however, VP_{AHPND} infection decreased levels of *stearoyl co-A decarboxylase* (*SCD*) transcripts and its downstream product, oleic acid (C19:1n-9), along with the levels of C14:0, C15:0, C16:0, C16:1n-7, C18:1n-9, and C18:3n-3. This coincided with the reduction of several lipid classes, including cholesteryl ester (CHE), TAG, phosphatidylethanolamine (PE), phosphatidylcholine (PC), phosphatidylglycerol-phosphatidylserine-phosphatidylinositol (PG-PS-PI), and total lipid. Lastly, although shrimp intestines were not the target site for VP_{AHPND} colonization or the secretion of Pir-like toxin, the transcription levels of *acetyl CoA carboxylase* and *fatty acid synthase* genes, which regulate rate-limiting steps of fatty acid synthesis pathway, increased in intestines of VP_{AHPND}-infected shrimp, which was supported by higher levels of C18:1n-9, C20:5n-3, and free fatty acids in the VP_{AHPND}-infected shrimp than the control shrimp. These findings confirm that VP_{AHPND} infection altered the eicosanoid biosynthesis and lipid metabolic pathways in shrimp gastrointestinal tract. This data is key to (1) establish the roles of eicosanoids in shrimp immunity, (2) understand the roles of lipid utilization in host-pathogen responses, and (3)

create eicosanoid and lipid profiles for the characterization of future newly emerging diseases.

Conclusion:

VP_{AHPND} infection in *P. vannamei* resulted in inflammation in gastrointestinal tract as demonstrated by increasing levels of pro-inflammatory signaling molecules, namely $PGF_{2\alpha}$ in hepatopancreases and PGE_2 and $PGF_{2\alpha}$ in intestines. VP_{AHPND} infection increased the levels of *COX*, *PGES1* and *PGES2* transcripts in hepatopancreases and the levels of *PGFS* transcripts in intestines. Moreover, VP_{AHPND} infection altered the levels of lipid class and fatty acids in shrimp gastrointestinal tract by suppressing oleic acid biosynthesis in hepatopancreases and inducing fatty acid synthesis in intestines. This data may be used as markers to gain a better understanding of newly emerging diseases in the future.

Current Output:

Yotbuntueng, P., Jiemsup, S., Deenarn, P., Tobwor, P., Yongkiettrakul, S., Vichai, V., Pruksatrakul, T., Sittikankaew, K., Karoonuthaisiri, N., Leelatanawit, R., Wimuttisuk, W. (2022) Differential distribution of eicosanoids and polyunsaturated fatty acids in the Penaeus monodon male reproductive tract and their effects on total sperm counts. PLOS ONE 17(9): e0275134. https://doi.org/10.1371/journal.pone.0275134

Kamonluk Kittiwongpukdee, Sukanya Saedan, Natthinee Munkongwongsiri, Wananit Wimuttisuk, anapong Kruangkum, Charoonroj Chotwiwatthanakun, Kallaya Sritunyalucksana, Rapeepun Vanichviriyakit, *Enterocytozoon hepatopenaei* infection causes lipid droplet depletion and increased cyclooxygenase in the hepatopancreas of *Penaeus vannamei*, The 45 th Anatomy Association of Thailand Conference 2022. May 3rd – 5th, 2023.

Challenges/Problems and Possible solutions:

The current technique to induce WFS only has 60% success rates in a small-scale experiment. As our lipidomic analysis required a large number of samples, we need to set up several rounds of WFS challenge to obtain the necessary amount of shrimp tissues for the analysis.

The second problem is due to the quantitative analysis of eicosanoids in shrimp organs. As the levels of eicosanoids varied within and among different organs, this resulted in certain eicosanoids exceeding the limit of quantification. As our attempts to re-analyze the extracts were unsuccessful, the data will be presented as semi-quantitative analysis.

Future plan:

We are in the process of inducing WFS in *P. vannamei* and hope to obtain sufficient amount of samples for the analysis of eicosanoids and lipid metabolic pathways in shrimp gastrointestinal tract. We will try to push for more publication in this coming year.

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Innovative Nanotechnology Approach for Shrimp (*Litopenaeus vannamei* and *Macrobrachium rosenbergii*) Shelf-life Extension Using Plant-based Bioactive Compound

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Project duration: 3 years, from 1 April 2023 to 31 March 2026

Current progress: 100%

Abstract:

Green tea spent (GTS) was extracted using 80% ethanol and examined for total chlorophyll content (TCC), total phenolic content (TPC), and antioxidant activities. Additionally, dechlorophyllization was conducted using sedimentation, and prior chloroform treatment to GTS powder. The results indicated that the sedimentation process remarkably reduced the TCC compared to chloroform treatment ($p < 0.05$). However, higher TPC and DPPH radical scavenging activity were noted in the extract with chloroform dechlorophyllization in comparison with sedimentation or control (without dechlorophyllization) ($p < 0.05$). The result showed that dechlorophyllization methods reduce total chlorophyll content while increasing the TPC and antioxidant activity compared to the control (GTSE). Therefore, decholorophyllization process could be useful to remove the green color and enhance the TPC and antioxidant activities of GTSE for the shelf-life extension of shrimp during storage.

Rationales/Problem statements:

Shrimp and shrimp products are widely consumed all over the world because of their delicacy and nutritional value. In 2020, the worldwide shrimp market was 18.30 Billion USD and is expected to grow to 23.4 Billion USD by 2026. Southeast Asia holds more than 80% of global shrimp production and in Southeast Asia, Thailand is the leading exporter of farmed shrimp (*Litopenaeus vannamei*) to Europe, USA, Japan, and South Korea**.** To extend the shelf-life and prevent the melanosis formation in shrimps, synthetic melanosis inhibitors have been used. Sulfites and their derivatives were widely used commercial additives for melanosis retardation. However, sulfating agents are known to produce allergic reactions and serious disturbances in asthmatic subjects. Therefore, plant polyphenols with antioxidant and antimicrobial activities could be a promising alternative to synthetic chemical**s.** Furthermore, the exploitation of agriculture processing waste for the recovery of added value compounds offers a new avenue for waste management, industrial growth, and the country's economy.

Objectives:

- To extract the polyphenols from agricultural waste including green tea spent.
- To de-chlorophyllize the extract and investigate the total phenolic content, antioxidant, antimicrobial, and PPO inhibitory activity of extracts.
- To analyze the phytochemical profile in the extract exhibiting the highest bioactivities and standardize the extract concerning the presence of major active compounds.
- To determine the efficacy of SAE against food spoilage bacteria, oxidative changes, and discolorations of shrimp (*Litopeneuas. Vannamei*) during refrigerated storage.
- To increase the shelf-life and quality of shrimp through edible nanoemulsion coating.
- To investigate the effect of dietary supplementation with SAE on shrimp

performance during shrimp aquaculture and melanosis of harvested shrimp during chilled storage.

Progress/Findings/Results:

The first six-month progress of the project is achieved. Green tea spent (GTS) as a raw material was selected to obtain the polyphenols basically catechin, which is known for its antioxidant and antimicrobial activities. The control sample consisted of GTS extracted using 80% ethanol which was high in TCC. To reduce the green color sedimentation, prior chloroform treatment to GTS powder was applied. The results indicated that both treatments reduced TCC and enhanced TPC and antioxidant activity. Among both treatments, decholorphyllization with chloroform showed higher TPC and antioxidant activity ($p < 0.05$). Therefore, decholorophyllization process could be useful to remove the green color and enhance the TPC and antioxidant activities of GTSE. Besides this, the effect of different solvents (acidified water, 25 ethanol, and 50% ethanol) extraction on TCC, and TPC is in progress for optimization and standardization.

Conclusion:

Green tea spent (GTS) as raw material has been selected. Further, different methods have been investigated for dechlorophyllization of GTS. Also, to enhance the TPC and antioxidant activity of GTS extract while lowering chlorophyll content, different green solvents (water, acidified water, and 25% ethanol) have been screened. The result suggests that although sedimentation and chloroform treatment drastically reduced the TCC in the extract, safer and less time-consuming processes are preferred. Hence, optimization of catechin-rich extract using 25% ethanol and acidified water will be carried out for future work.

Current Output:

Koirala, P., Nirmal, NP., Woraprayote, W., Visessanguan, W., Bhandari, Y., Karim, NU., Nor-Khaizura, MAR., Saricaoglu, FT. (2023) Nano-engineered edible films and coatings for seafood products. *Food Packaging and Shelf Life* 38, 101135 **(Q1, Top 10%)**

Challenges/Problems and Possible solutions: NA

Future plan:

- To analyze the phytochemical profile in the extract exhibiting the highest antioxidant and PPO inhibitory activities
- To standardize the extraction concerning the presence of major active compounds.
- To determine the efficacy of SAE against food spoilage bacteria, oxidative changes, and discolorations of shrimp (*Litopenaeus Vannamei*) during refrigerated storage.

Tailoring Pulse Proteins for Targeted Development of Sustainable Foods (PulsePro)

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Project duration: 3 year, from 01 April 2023 to 31 March 2026

Current progress: 12%

Abstract:
This project is a collaboration among three institutes, including Wageningen University & Research, TU Berlin, and MTEC under the *7th JFS Program: Southeast Asia-Europe Joint Funding Scheme for Research and Innovation*. So far, the work at MTEC has been focused on the extraction of pulse proteins using wet processing through alkaline-isoelectric precipitation method. Two types of pulses, i.e., mung bean (MB) and pigeon pea (PP), that are widely cultivated in Thailand, were primarily studied. Different protein extracts, including globulin-rich (protein isolate) and albumin-rich fraction, were obtained. The results showed that the globulin extract had high protein contents of 90.39 ± 0.90 and 84.02 ± 0.70% (w/w), while the albumin extracts showed lower protein purities of 18.07 ± 0.67 and 19.64 ± 0.48% (w/w) but with higher carbohydrate contents for MB and PP, respectively. The techno-functional properties as well as structure of the protein extracts were also characterized to gain more understanding on the structure-property-processing relationship of these proteins. Overall, the work has advanced according to the established planned.

Rationales/Problem statements:
A global transition from animal-based to more sustainably produced plant-based proteins is an essential element to reach the United Nations strategic development goals to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. According to the United Nations, already today more than 2 billion people are without food or unable to eat a healthy balanced diet on a regular basis. As the global population is projected to reach nearly 10 billion in 2050, it is predicted that the food demand will increase by more than 50%. Consequently, we are facing an enormous challenge to close the food gap in order to achieve a sustainable food production and an adequate availability of high quality, affordable foods. There is wide consensus that a transition from diets based on animal proteins towards diets primarily based on plant proteins can contribute significantly to achieving the UN strategic goals. This has resulted in significant increases in investments in various plant-based foods in the last five years both in Europe and Asia-pacific region. As such, there is clearly a shared interest in this research area between the two regions, and therefore good reasons to mutually invest in research in this growth area, in order to contribute to the goal of a more sustainable global food production.

Objectives:
The overall objectives of the proposed research are:
1) To identify for a range of pulses (legumes), the generic physicochemical properties that control their techno-functionality (gelling, emulsifying, and foaming behavior),
2) To examine how these properties are affected by extraction and modification processes,
3) To establish which (combination of) these processes are optimal, both from a sustainability and functionality perspective.

Progress/Findings/Results:
The first six month of this work has focused on extraction of pulse proteins from mung bean (MB) and pigeon pea (PP) using an alkaline-isoelectric precipitation method. This results in

two main protein fractions, i.e. albumin-rich and globulin-rich or protein isolate fraction. The former has protein content lower than 50% and is high of carbohydrate which is predominantly plant cell wall polysaccharides. On the other hand, the latter fraction shows higher protein purity above 80%. In particular, higher protein content was found in the globulin-rich MB protein (90.39±0.90%) compared to that of the PP protein (84.02±0.70%). The protein profile of globulin-rich MB protein shows a major vicilin-type (8S) at subunits between 25-75 kDa, followed by legumin-type (11S) and basic-type (7S). For globulin-rich PP protein, it was observed that the vicilin-type (7S) at subunits 50 and 70 kDa were the most intensify. The secondary structure analyses using the circular dichroism technique revealed that the extracted pulse proteins are predominantly β-sheet structure as opposed to the α-helix structure, typically found in animal-based proteins. This difference in the structure is expected to contribute to the difference in techno-functionalities of these proteins. Furthermore, the analyses on techno-functionalities of different fractions of extracted pulse proteins were performed. It was found that the globulin-rich fractions of both MB and PP proteins exhibited low solubility at pH between 4 to 5, which is near to their isoelectric point (pI). Increasing ionic strength improved the solubility, especially at the pI, as a result of the salting-in phenomenon. The emulsification experiment also showed that the globulin-rich fractions had higher Emulsion Ability Index (EAI) than that of the albumin-rich fractions for both pulses. However, the albumin-rich fractions revealed higher Emulsion Stability Index (ESI) which may be attributed to its high polysaccharide content or the lower molecular weight that could have stabilized the fluid-fluid interface more effectively than the larger molecular weight Globulin-rich fraction. On the contrary, the foaming properties showed that the albumin-rich fraction were of higher foaming capacity and stability than those of the globulin-rich fraction for both MB and PP. These preliminary results show the promising potential of the pulse proteins that can be used to complement the animal-based proteins in various applications in food industry. Nonetheless, more in-depth analyses on the emulsification and foaming properties of the extracted pulse proteins are being studied using dilatational/interfacial rheology in order to gain better knowledge on how these proteins are adsorbed and stabilize at the liquid-liquid or air-liquid interfaces, respectively.

Conclusion:

Extraction of proteins from two types of pulses, i.e., mung bean (MB) and pigeon pea (PP), using wet processing through alkaline-isoelectric precipitation method was investigated. Different protein extracts, including globulin-rich (protein isolate) and albumin-rich fraction, were obtained. The secondary structure of these proteins were predominantly β-sheet as opposed to α-helix found in animal-based proteins. The globulin-rich fraction showed higher protein purity compared to the albumin-rich one, which was constituted with a higher carbohydrate content. While, the globulin-rich exhibited better emulsification property, the albumin-rich fraction demonstrated superior foaming property. The differences in these protein functionalities can provide an advantage in the development of more precisely targeted and high-quality plant-based food products.

Current Output:

Invited talk at the ASEAN-ASSET 2023 meeting during 14-15 November 2023. The presentation is entitled “Tapping the potential of pulse proteins: From refinement extraction to its protein functionality”

Challenges/Problems and Possible solutions: None

Future plan:

Protein extraction on other pulses, i.e., lentils, lupins, and fava bean, are being carried out. Their functionalities will subsequently be analysed and reported in the next progress report.

Genetics, Genomics and Breeding Research on Food Legume Crops

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Project duration: 3 years, from 15 December 2021 to 15 December 2024
Current progress: 70%

Abstract: The objectives of this project are to (i) investigate inheritance and locate QTLs for breeding of traits related to stress resistance, seed dormancy and yield of legume crops of the genus *Vigna* including mungbean, black gram, cowpea and zombi pea and (ii) build up research connection and partnership on genomics and breeding of legume crops with research institutes in Asia and Europe In the first two years of the project, we have identified major QTLs and candidate genes for seeds dormancy in wild species of mungbean, black gram, cowpea and zombi pea, resistance to bruchids in wild moth bean, pea and zombi pea, seed size in mungbean and rice bean, resistance to powdery mildew disease and leaf spot disease in mungbean, flowering time in mungbean and rice bean, and salt tolerance in mungbean. We have established close research collaboration with research institutes in in China, Taiwan, Japan, Korea, and England.

Rationales/Problem statements: Legume crops/plants are an important source of nutrients for humans and animals. Proteins from legumes are gaining attention and popularity for production of plant-based meat. There is an increasing trend in consumption of legumes. However, constrains of legume crop production is low yield and infestation by insect and diseases. Climate change negatively affects yield and production of crop plants including legumes by exacerbating abiotic and biotic stresses. Besides these problems, consumer and industry demands in use of legume crops are changing. Thus, new mungbean/yardlong bean cultivar(s) must possesses resistance to heat, drought, insects and diseases, high seed chemical contents or nutrients to fit the consumer and industry demands. Knowledge on genetics and genomics are indispensable for plant breeding in which they provide more precision and efficiency in plant selection, and thus higher chance of success. Therefore, it is necessary to generate knowledge on genetics and genomic tools for breeding of new legume crops.

Objectives: To (i) investigate inheritance and locate genes/quantitative trait loci (QTLs) for breeding of traits related to biotic and abiotic stress resistance, seed dormancy and yield of legume crops, especially mungbean and (ii) build up research connection and partnership with research institutes and/or universities in China, Japan, Korea, and England on the legume crops.

Progress/Findings/Results: We have located QTL controlling seeds dormancy in wild mungbean, wild black gram, wild cowpea and wild zombi pea, resistance to bruchids in wild moth bean, pea and zombi pea, seed size in mungbean and rice bean, resistance to powdery mildew disease and Cercospora leaf spot disease in mungbean, flowering time in mungbean and rice bean, and salt tolerance in mungbean. Most of the QTLs identified were validated and/or confirmed. Candidate genes were identified for some of those traits including *KNOTTED-LIKE HOMEOBOX OF ARABIDOPSIS THALIANA 7* for seed dormancy in wild mungbean, *2-beta-dioxygenase 1-like* gene and *Calmodulin-like* gene for seed dormancy in wild zombi pea and *Caffeoyl coenzyme A O-methyltransferase 1* for seed dormancy in wild cowpea, *polygalacturonase-inhibiting protein 2* for bruchid resistance in wild moth bean, *xylanase inhibitor* bruchid resistance in pea and wild zombi pea, *Recognition of Peronospora parasitica 13* for powdery mildew resistance in mungbean, *Xa21-like* gene for leaf spot

resistance in mungbean, *KINASE-INDUCIBLE DOMAIN INTERACTING8* for seed size in mungbean, CYP78A6 for seed size in mungbean, *FRUITFUL*, *FLOWERING LOCUS T* and *PSEUDO-RESPONSE REGULATOR 3* for flowering time in rice bean, and *Phytochrome E* for flowering time in mungbean, and *TERMINAL FLOWER1* affecting stem determinacy.
Research connection and partnership have been made with Chinese Academy of Agricultural Sciences, Jiangsu Academy of Agricultural Sciences, Shanxi Agricultural University, Guangxi Academy of Agricultural Sciences, Beijing Academy of Agriculture and Forestry Sciences, and Yangtze University in China, National Agriculture and Food Research Organization in Japan, and University of Nottingham in England.
Conclusion: Genome regions and candidate genes for yield-related traits, adaptation, and biotic stress resistance have been identified in mungbean, cowpea, rice bean, zombi pea, and pea. Research collaborations been made with several research institutes in foreign counties.
Current Output: Seven research articles have been published and 3 research articles have been submitted.
Challenges/Problems and Possible solutions: None
Future plan: Application for international research fund for genomics and breeding research of legume crops.

Genome Editing Mungbean (*Vigna radiata* L. Wilczek) For Resistant Starch Production Type II (RS2)

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 60%

Abstracts:

Resistant starch type 2 is gaining more attention in the functional food industry due to its health benefits and the possibility of organic production. With a short life cycle of around 2.5 months, mung bean starch serves as a valuable source of amylose. However, the resistant starch content in Thai mung beans remains low, comprising only around 8-9% of the total starch. Transcriptomic analysis suggested a few candidate genes—Protein Targeting to Starch, starch synthase 3, and starch branching enzyme 1—for high resistant starch production. At least two single guide RNAs (sgRNAs) were designed to bind to an exon of each candidate gene. Subsequently, these sgRNAs were mixed with the Cas protein and transformed with the aid of polyethylene glycol to facilitate the uptake of ribonucleoprotein into the protoplast nucleus. The editing efficacy will be evaluated through Indel Amplicon Analysis, a method currently undergoing protocol optimization in collaboration with a company in Thailand. The parallel agrobacterium transformation on callus and cotyledonary nodes is still in progress.

Rationales/Problem statements:

Most of the resistant starch (RS) in Thailand is either imported or chemically modified from cassava starch. RS type 2 has high value and is accepted for use in organic products. Considering the strict regulations on genetically modified crops, DNA-free genome-edited crops might be a solution for these complicated crop registrations. Moreover, mung bean is a cash crop that requires a small amount of water and can grow in almost every part of Thailand, with its high amylose content and unique starch characteristics. Therefore, using mung bean as a model crop plant for DNA-free genome editing is promising.

Objectives:

To generate high resistance starch mung bean by using CRISPR/Cas system

1. To develop a protocol for protoplast isolation and ribonucleoproteins (RNP) transformation for DNA free genome editing in Thai mung bean
2. To establish an efficient and high throughput screening protocol for editing at the cell pool level.
3. To develop protocols / methods for regeneration of edited single protoplast
4. To study the starch structure and properties of the marker-free genome edited mung bean
5. To identify the mechanisms of high resistance starch production in mung bean
6. To evaluate the fitness and physiological responses to field condition in Thailand

Progress/Findings/Results:

The protocols for protoplast isolation, purification, transformation, and culture have been successfully implemented. It was observed that the concentration of protoplasts from mung beans is significantly higher than that from the potato protoplasts provided by our collaborators. Modifications to the isolation buffers were necessary, resulting in a final mannitol concentration of up to 0.7M. However, the elevated mannitol concentration impeded integration and cell wall formation in the protoplasts, leading to adjustments in the culture media to reduce mannitol concentration. The sgRNAs for the candidate genes have been designed and are awaiting synthesis. Agrobacterium transformation has been carried out in both calli and cotyledonary nodes.

Despite these advancements, the regeneration of mung bean calli remains problematic. In addition to the necessary modifications to the media, the light spectrum in the culture room is identified as an influencing factor. Addressing these concerns and modifying the growing conditions pose ongoing challenges.

The partnership plan is currently in progress, with the main collaborator from the University of Copenhagen planning to visit SUT around the end of January 2024 for a duration of 2-3 weeks. During this visit, discussions will be held regarding potential solutions to current challenges, and a new collaborative grant proposal will be developed for other aspects of mung bean genome editing. Furthermore, an additional collaborator with expertise in CRISPR/Cas agrobacterium transformation and the Sugar Starvation Response (SSR) at the University of California, Davis, USA, will also be supporting this project.

Conclusion:

The project is several-months-delay with the previous contamination problems but the problems is solved. The genome editing, transformation, evaluation and callus regeneration is in progress, which might lead to the delay of the final output of this project for around 5-6 months.

Current Output:

1. Submitted manuscript on transcriptomic analysis of mung bean seeds at different developmental stages (submitted to Frontier in Plant Science)
2. Protocol on mung bean protoplast transformation

Challenges/Problems and Possible solutions:

1. Contamination problem from Agrobacterium in Agrobacterium transformation in cotyledon**.**
   Solution: Try the combination of antibiotic in culture media
2. The root formation problem in tissue culture derived from cotyledon node, was not consistent among each batch.
   Solution: Try new media with different hormone concentrations and combinations.
3. Some affordable platform of sgRNA synthesis and the IDAA are not available in Thailand.
   Solution: Develop our own platform to synthesis and analyze the results in our own affordable way with companies in Thailand.

Future plan:

1. Invite the Danish collaborator to SUT during January and February 2024, and organize a seminar on genome editing and starch bioengineering.
2. Develop the platform that more affordable to perform the RNP transformation and IDAA analysis in Thailand.
3. Rush up all the process to be able to achieve all purposes in time.

Characterization of Salt Tolerance Genes in Rice and Their Mechanisms via Genomics and Transcriptomic Analysis

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 60%

Abstract:

OsBTBZ1 is homologous to *AtBT3* gene in Arabidopsis. Therefore, the *Atbt3* Arabidopsis mutant line was used to validate the function of *OsBTBZ1* under salt stress. The *OsBTBZ1*::*GFP* expression in the onion epidermal peel indicated nuclear localization. *Atbt3* mutant showed salt susceptibility, while the ectopic expression of *OsBTBZ1* could reverse the phenotypes at both germination and seedling stages, supporting the role in salt tolerance. The transcriptomic and genomic comparison between CSSL16 and 'KDML105' also predict *OsERD4* as one of the sat tolerance genes. It has a similarity with OSCA1.1 which encodes the water sensor protein. The base substitution and deleting in *OsERD4* gene in CSSL16 were detected. The yeast experiment showed the different growth rate in salt tolerant phenotypes with *CSSL16_OsERD4* and *KDML105_OsERD4* expression. Further investigation with the overexpression or knock-down expression in rice is in the process.

Rationales/Problem statements:

Based on genome and transcriptome analysis of CSSL16, the salt tolerance rice line, nine genes were predicted to be responsible for salt tolerance in rice. At least two genes, *OsBTBZ1* and *OsERD4* are selected to validate their functions in salt tolerance by using *Arabidopsis* mutant models with the T-DNA insertion at the homologous genes. The ectopic expression of selected genes will be performed in Arabidopsis and the phenotyping of the revertant lines (in the mutant background) and the ectopic expression lines (wild type background) will be used to validate the salt tolerance functions. Moreover, the yeast mutant with salt susceptibility due to the transmembrane proteins regulating the ion transport knocked-out will be used to characterize OsERD4 as it is predicted as the transmembrane protein with the similarity with osmotic sensor in Arabidopsis, OSCA1. After validation, the information can be used in rice breeding program in the future.

Objectives:

1. To validate that *OsBTBZ1* and *OsERD4* are salt tolerant genes in rice
2. To investigate the salt tolerant mechanisms of *OsBTBZ1* and *OsERD4* expression by gene co-expression networks

Progress/Findings/Results:

1. *OsBTBZ1* was predicted to be involved with salt tolerance in rice by combining the

transcriptomics and genomic datasets of chromosome substitution line 16 (CSSL16), the salt tolerant line and its parental cultivar, Khoa Dawk Mali 105 (KDML105) rice. Based on the STRING database, *OsBTBZ1* was associated with other abiotic stress-related proteins. The highest expression of *OsBTBZ1* was observed in the sheaths of young leaves. The OsBTBZ1-GFP fusion protein was localized to the nucleus, supporting a transcriptionally regulatory role for this protein. The *bt3 Arabidopsis* mutant line exhibited susceptibility to NaCl and abscisic acid (ABA) but not to mannitol. NaCl and ABA decreased the germination rate and growth of the mutant lines. Moreover, ectopic expression of *OsBTBZ1* rescued the phenotypes of the *bt3* mutant line and enhanced the growth of the wildtype *Arabidopsis* under stress conditions. These results suggest that *OsBTBZ1* is a salt-tolerant gene functioning in ABA-dependent pathways.

2. Comparison of coding sequence of *OsEDR4* or *OSCA2.5* from CSSL16 and KDML105 revealed that there were 5-point mutations leading to the changes in amino acids, Y165H, F186Y, Q215R, E230K and R653H. Moreover, there was a deletion in OSCA2.5 of KDML105 resulted in the lost of 5 amino acids in TM9 in OSCA2.5 of CSSL16. The expression of *OSCA2.5* from CSSL16 and from KDML105 in salt susceptible yeast mutant lines containing Nha1 (encoding Na^+/H^+ antiporter) and Ena1-Ena4p (encoding Na^+-ATPases proteins) knocked-out under salt stress condition showed that the yeast strain with expression of *OSCA2.5* from CSSL16 could grow better that the strain with *OSCA2.5* cDNA from KDML105, suggesting the importance of these mutations in *OSCA2.5* in salt tolerance. The Aterd4 knocked-out mutant showed susceptibility to salt stress. The overexpression Arabidopsis lines in *Aterd4* mutant and wild type are being regenerated.

Conclusion:

1. *OsBTBZ1* is the transcription factor regulating salt tolerant via ABA dependent pathway and located on salt tolerant QTL on chromosome 1. Its expression suggested that it was responsible for salt tolerance at seedling stage of rice.

2. *OsERD4* or *OSCA2.5* encodes the cation channel protein. It was predicted to be transmembrane protein. The SNPs in coding region of *OsERD4* between KDML105 and CSSL16, the salt tolerant chromosome substitution line with KDML105 genetic background resulted in the difference in salt tolerant ability in the yeast strain with *nha1* and *ena1-4* deletion, suggesting these SNPs were responsible for salt tolerance.

Current Output:

Saputro, T. B., Jakada, B. H., Chutimanukul, P. Comai, L. Buaboocha, T., Chadchawan, S. (2023). *OsBTBZ1* confers salt stress tolerance in *Arabidopsis thaliana*. International Journal of Molecular Sciences. 24: 14483.

Challenges/Problems and Possible solutions:

Rice transformation and engineering the large fragment in some rice expression vector are still problematic. We are in the process of vector engineering by using the engineering kit for large fragment and develop the rice transformation protocol.

Future plan:

1. Create the overexpression / knocked out transgenic rice lines to investigate the function of *OsBTBZ1* and *OsERD4*.

2. Investigate the transcriptome of Arabidopsis with ectopic expression of *OsBTBZ1*, which conferred salt tolerance.

Research and Development Network for the Rearing of Honey Bee (*Apis Mellifera* L.) Brood and Its Potential as A Novel Alternative Protein Food Source

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Project duration: 2 years, from 1 November 2021 to 30 October 2023

Current progress: 95%

Abstract:

Our research network has compiled and synthesized a body of knowledge to share with the beekeepers who participated in the project. This information can be utilized by beekeepers to enhance production efficiency and environmentally friendly management practices for bee product processing. Throughout the project, research topics were selected to seamlessly integrate into the honey bee production chain, spanning from upstream to downstream processes: 1) Novel application of probiotics and enzymes derived from microorganisms to enhance the production of supplementary feed for honey bees 2) Improvement of efficiency in honey bee production and the processing of bee-derived products 3) Economic analysis of honey bee brood as a commercially viable source of insect protein 4) Establishment of a cooperative network involving government, private, and educational institutions within the realm of honey bee brood rearing, exploring its potential as an innovative alternative protein food source.

Rationales/Problem statements:

Exploring honey bee brood as a protein source reveals potential integration into the human diet, especially in culturally supportive tropical regions. Acknowledged for its nutritional richness and deliciousness, honey bee brood stands as a potential high-value product and has the potential to be a functional food ingredient. However, the realization of this potential depends upon the development of an environmentally friendly production process, which is crucial for ensuring sustainability in its utilization. This study aims to significantly contribute to the evolving field of edible insect proteins by investigating brood production, delineating functional properties, and exploring diverse food applications. Addressing gaps in understanding production, properties, and applications, the research aims to pave the way for sustainable honey bee brood utilization. Additionally, it endeavors to identify challenges, perspectives, and areas for further exploration, laying a foundation for broader advancements in edible insect proteins within a concise framework.

Objectives:

1) Establish a research network that focuses on honey bee brood production as a unique alternative protein source within the farm system. 2) Formulate a nutritionally balanced feed

formula for optimal qualitative and quantitative development of bee broods. 3) Assess the nutritional value and safety of bee larvae as a protein source. 4) Disseminate knowledge regarding the production of bee larvae as high-quality protein food to both the commercial and public sectors.

Progress/Findings/Results:

The findings and results from the project, following the project's objectives, are as follows: 1) Establishment of a Research Network: We have made significant strides in establishing a robust research network dedicated to honey bee brood production as an innovative protein source within the farm system. We have initiated collaborations with key stakeholders and experts from Thailand and overseas, establishing the foundation for a comprehensive exploration of this alternative protein. Our team has made substantial progress in formulating a nutritionally balanced feed formula tailored for the qualitative and quantitative development of bee broods. Our team has conducted extensive research to ensure optimal nutrient composition, fostering healthy growth and development. 3) Nutritional Value and Safety Assessment: Researchers have assessed the nutritional value and safety of honey bee brood as a protein source, investigating the potential use of bee brood powder as a food ingredient. The findings indicate promising nutritional attributes, and safety protocols are in place to ensure consumer well-being. 4) Knowledge Dissemination: Efforts to disseminate knowledge on bee larvae production as a high-quality protein food have been initiated. Preliminary outreach activities include workshops, seminars, and informational materials targeting both commercial entities and the public. This outreach aims to raise awareness and promote the adoption of bee larvae as a sustainable protein source. Overall, these achievements reflect our commitment to advancing research and promoting the integration of honey bee broods into the agricultural and dietary landscape as a viable protein alternative. Notably, we have presented five research topics through posters and oral presentations at both national and international conferences. Additionally, our team has contributed significantly to academic literature, with four papers published in Scopus and ISI databases and another manuscript currently under review in a Scopus-indexed journal. This collaborative endeavor has yielded substantial support, with three national and three international grants secured. Furthermore, we have successfully developed three prototype products: honey bee brood-boosting supplementary feed, honey bee brood powder, and honey bee brood protein bars.

Conclusion:

Honey bee brood has a high protein content, encompassing all essential amino acids crucial for a healthy diet and presenting a promising alternative protein source for the world's expanding population. Honey bee brood as an insect protein holds potential as an alternative protein source in food formulations. Nevertheless, additional comparative studies are imperative to evaluate the functionality of honey bee brood and processing techniques. Our network is to advocate for bee brood as a widely accepted food source, serving as a replacement for protein sources that are considered costly, overused, and environmentally unfriendly.

Current Output:

Conference presentation: 5 topics

National: 1) Utilization of Agricultural Materials and by-products to produce artificial pollen substitute for rearing honey bees (*Apis mellifera* L.): Annual Meeting of the Animal Nutrition Division, Department of Livestock Development (Poster). 2) Optimizing Honey bees (*Apis mellifera* L.) Rearing through the Production of Artificial Pollen Substitute Using Agricultural Materials: the 12th Phayao Research Conference (Oral, *Best presentation award*). 3) Enhancing honey bee health through supplementary feeding from agricultural by-

products. **International:** 4) Enhancing honey bee health through supplementary feeding from agricultural by-products (Oral). 5) Leaf Protein Concentrates (LPC): A Supplementary Feed Source for Honey Bees in Natural Pollen-Deficient Areas (Poster) at The 10th EAFES International Congress 2023, Jeju, Republic of Korea

Publication: 4 papers and 1 under review: 1) Occurrence of an invertase producing strain of *Aspergillus niger* LP5 isolated from longan pollen and its application in longan syrup production to feed honey bees (*Apis mellifera* L.) (Journal of Ecology and Environment, Scopus Q2) (*Best Paper of the year 2022*). 2) Color Test Kit for Detecting Organophosphate and Carbamate Pesticides by Using Esterase Extract from Honey Bees (Philippine Journal of Science, Scopus Q 3). 3) Exploring the Functional Properties of Propolis, Geopropolis, and Cerumen, with a Special Emphasis on Their Antimicrobial Effects (Foods, ISI Q1, IF 5.2). 4) Isolation and Identification of Microorganisms and Antibiotic Resistance Microorganisms from Beehives Located in Palm, Corn and Longan Plantations, Thailand (Microorganism, ISI Q2, IF 4.5). 5) Detection of Microbial Organisms on *Apis mellifera* L. Beehives in Palm Garden, Eastern Thailand (*Under review/ 1st revision*) ((Journal of Ecology and Environment, Scopus Q2) **Product prototype:** 1) Honey bee supplementary diet for brood boosting 2) Honey bee brood protein powder. 3) Honey bee brood protein bar. C**ollaboration:** National level: 2 universities (CMU and UP) and 1 government sector (DLD), International level: 4 Universities (AU and OSU, USA; ANU, Korea and NCHU, Taiwan)**. National grant:** 3 grants (NIA and NRTC; 2 grants), **International grant:** 3 grants (AU, USA)

Challenges/Problems and Possible solutions:

In addressing challenges surrounding the integration of honey bee broods as an alternative protein source, our research prioritized developing an environmentally sustainable production process, ensuring long-term viability, and bridging knowledge gaps. We implemented meticulous research methodologies and promoted global collaborations, emphasizing nutritionally balanced feed and safety protocols to mitigate production challenges. Distribution efforts through workshops and scholarly publications have contributed to closing knowledge gaps. Ongoing initiatives focus on sustained collaboration, continuous production refinement, and engagement with diverse stakeholders. These collective measures aim to facilitate the sustainable utilization of honey bee broods and comprehensive knowledge broadcasting within a holistic framework.

Future plan:

Our future plan includes integrating honey bee broods into sustainable practices. We will refine our research network, prioritizing international collaborations to explore novel issues in honey bee management. Emphasizing environmentally friendly practices, optimizing the bee brood feed formula for enhanced bee health. Future efforts will focus on expanding knowledge through targeted workshops. Aligned with our commitment to promoting bee brood as a global protein alternative, we aim to secure additional funding for comprehensive research, contributing to academic literature, and developing innovative products based on bees.

Artificial Intelligence-guided Synthetic Biology for Bio-based and Biorefinery Industry

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Project duration: 2.5 year, from 1 November 2021 to 30 April 2024

Current progress: 80%

Abstract:

Development of cell factories and biocatalysts is the key on conversion of renewable carbon resources to bioproducts in biorefinery. This project aims to establish a frontier technology "AI-guided SynBIO" on application of artificial intelligence using machine learning on optimizing biochemical pathways in yeast cell factories developed by synthetic biology on production of biofuels and biochemicals as well as on optimizing bioprocesses for production of the target products. Advanced in silico computational modelling has been applied for determining protein structure and dynamics in enzyme engineering. The works also extended to the study on molecular mechanisms on improving stress tolerance of the cell factories under harsh operational conditions in order to develop the high-performance microbial strains for industrial application. The project is based on closed collaboration between Thai research institutes, led by BIOTEC with the State Key Laboratory of Microbial Metabolism, Shanghai Jiao Tong University with great expertise on synthetic biology in fungal systems and application of AI in life sciences.

Rationales/Problem statements:

Application of artificial intelligence and advanced computational tools on guiding design and construction of cell factories and biocatalysts is the potent strategy on expediting the development process and improving the performance of the microbes and enzymes in biorefinery. The "Design-Built-Test-Learn" (DBTL) concept guided by machine learning, starting from (i) conceptual design of the cells or biocatalysts, followed by (ii) experimental construction and assemble of the combinatorial library, (iii) evaluation on performance of the respective variants and collecting relevant omics data, and (iv) analysis of the collected biodata by ML models, is the core approach on AI-guided development of cell factories and enzymes with higher performances in a shorter time. Enzyme engineering can also be supported by advanced *in silico* computational tools on predicting structures and dynamics of the enzymes under simulated conditions. Integrating the multidisciplinary knowledge on AI-guided life science research will be focused in this network strengthening project.

Objectives:

(1) To construct combinatorial library of *S. cerevisiae* targeting on mevalonate pathway for studying the effects of target genes encoding enzymes in rate limiting step of Farnesyl diphosphate (FPP), by varying expression levels
(2) To evaluate performance of yeast combinatorial library for production of FPP and specific growth rate along with gene expression analysis
(3) To develop machine learning model for optimization of genes related to FPP synthesis for optimal combinatorial genetic alteration
(4) To construct the optimal yeast strain according to ML model for maximized FPP

production

(5) To further modify the optimal FPP-producing yeast for a selected commercially potent product

(6) To development ML model for optimization of bioprocess conditions

The work is extended to exploration of SynBio for development of cell factories for other products with commercial potential, application of advanced computational modelling for enzyme engineering, and investigation of stress response genes for improving tolerance of microbial strains under operational conditions.

Progress/Findings/Results:

At this stage, we have completely demonstrated the application of machine learning to optimize the expression levels of key genes in ethanol production by *S. cerevisiae*. Biodata on ethanol yield, glucose utilization, cell density, and metabolite profiles were collected from the yeast combinatorial library at 30^{o}C comprising 216 combinations of key genes (PDC1, ADH1, and TPS1) using 6 expression levels using different promoters (TDG3, ENO2, PGK1, YEF3 and ACT1 and control). Using XBoost for supervised training algorithm could predict the candidate combinatorial strain for ethanol production at 40^{o}C with 4.2% higher ethanol yield. The knowledge has been applied for designing yeast cell factory for production of isoprenoids. A combinatorial yeast library comprising three key genes in the mevalonate pathway (EfmvaE, EfmvaS, and ERG20) under the control of 14 promoters and 15 terminators have been constructed. Candidate strains producing beta-carotene at varying levels were selected for collecting input data for subsequent application of ML to predict the optimal strain for production of beta-carotene and other valuable isoprenoid products. The application of ML on optimization of bioprocess for production of beta-carotene is also on plan. In addition, we have worked with SJTU to study the stress response genes in yeasts by investigating the effects of flocculation gene ScFlo from *S. cerevisiae*. Expression of this gene in *Pichia pastoris* engineered for D-lactic acid production improved tolerance to harsh conditions in the production process. We also worked on development of cell factories for production of meso-galactaric acid from agricultural by-product using enzyme produced by an engineered *Trichoderma reesei* strain overexpressing polygalacturonase to degrade pectin to galacturonic acid, which will then further converted to the target product by *S. cerevisiae* strain expressing GatA transporter and uronic dehydrogenase engineered by *in silico* site saturation mutagenesis. In addition, we also worked with SJTU on applying computational molecular dynamic simulation through quantum mechanic analysis to elucidate the basis of thermostability of the hyperthermophilic engineered xylanase X11PNQ, developed in our laboratory, which is considered one of the most thermotolerant xylanase reported. The *in silico* simulation techniques demonstrated construction of H-bonding network and pi-amide interactions to thermostability of the enzymes. Along with research in Thailand, the SJTU team also worked on exploring several stress response genes in yeasts and application of ML on bioprocess optimization. On networking, we have extended the collaboration by setting up a research network on synthetic biology between BIOTEC-SJTU and other leading universities in Thailand (KU, KMUTT, and Mahidol). The work will provide the knowledge on establishing the application of AI and advanced computational tools for microbial and enzyme engineering for Thai researchers aimed in this project.

Conclusion:

The frontier knowledge on AI-guided SynBio, focusing on application of machine learning and advanced computational modelling for protein structure and dynamics for designing microbial cell factory and enzyme engineering has been established in this project. The research will be continued to complete the work plan. The work will strengthen the capability of Thai researchers in the field of synthetic biology and biocatalyst engineering through

collaboration with SJTU and other partner research institutions in the network.

Current Output:

International publications (Target 8: 6 published/ 1 submitted/ 1 final manuscript)

(1) Siamphan C, Arnthong J, Tharad S, Zhang F, Yang J, Laothanachareon T, Chuetor S, Champreda, Zhao X-Q, Suwannarangsee S* (2022) Production of D-galacturonic acid from pomelo peel using the crude enzyme from recombinant Trichoderma reesei expressing a heterologous exopolygalacturonase gene. Journal of Cleaner Production 331: 129958 (IF 9.297, Q1)

(2) Sae-Tang K, Bumrungtham P, Mhuantong W, Champreda V, Tanapongpipat S, Zhao X-Q, Liu CG, Runguphan W (2023) Engineering Flocculation for Improved Tolerance and Production of d-Lactic Acid in Pichia pastoris. Journal of Fungi 9(4): 409 https://doi.org/10.3390/jof9040409 (IF 5724, Q1)

(3) Khamwachirapithak, P, Sae-Tang, K Mhuantong, W, Tanapongpipat, S, Zhao, X-Q, Liu, C-G, Wei, D-Q, Champreda, V, Runguphan, W. Optimizing Ethanol Production in Saccharomyces cerevisiae at Ambient and Elevated Temperatures through Machine Learning-Guided Combinatorial Promoter Modifications, ACS Synthetic Biology, 12, 10, 2897–2908 (IF 4.7, Q1)

(4) Yang J., Yue H.R., Pan L.Y., Feng J.X., Zhao S., Suwannarangsee S., Champreda V., Liu C.G., Zhao X.Q. (2023) Fungal strain improvement for efficient cellulase production and lignocellulosic biorefinery: current status and future prospects. Bioresourc Technol 385: 129449 (IF 11.88, Q1)

(5) Huang X.Y., Ao T.J., Zhang X., Li K., Zhao X.Q., Champreda V., Runguphan W., Sakdaronnarong C., Liu C.G., Bai F.W. (2023) Developing high-dimensional machine learning models to improve generalization ability and overcome data insufficiency for mixed sugar fermentation simulation. Bioresour Technol 385: 129375 (IF 11.88, Q1)

(6) Zhang F.L., Zhang L. Wen D.W., Liao S., Fan Y., Champreda V., Runguphan W., Zhao X.Q. (2023) Engineering yeast cell factories to produce biodegradable plastics and their monomers: Current status and prospects. Biotechnol Adv. 68: 108222 (IF 16, Q1)

(7) Zhang M.M., Yuan B., Zhou M.H., Champreda V.,
Zhao X.Q. Zinc metabolism and stress tolerance: effects of zinc sulfate on global gene transcription of Saccharomyces cerevisiae and identification of novel key genes (submitted)

(8) Boonyapakron K., Keiser B.S., Prabmark K., Aiewviriyasakul K., Arunrattanamook N., Jaruwat A., Chitnumsub P., Tuck T.S., Zhao X.Q., Liu C.G., Wei D.Q., Champreda V.* (2023) Engineered hyperthermophilic xylanase from bagasse metagenome and its basis of thermophilicity by molecular dynamic simulation (final manuscript for submission)

Intellectual property

(1) Patent application “Whole yeast cell biocatalyst for production of D-galactaric acid” (in preparation)

Prototypes

(1) Engineered *S. cerevisiae* strain for beta-carotene production (on plan)

(2) Engineered whole yeast cell biocatalyst for production of D-galactaric acid (on plan)

Challenges/Problems and Possible solutions:

Due to Covid 19, the plan for researcher exchanges was suspended. However, the situation is now back to normal and the researcher exchange will be continued as planed in 2024.

Future plan:

The research in the next step will focus on the completing the remaining works on constructing the cell factories for production of the target bioproducts. The research network on advanced SynBio and biorefinery will be established between Thai research institutes with SJTU and will be extended to other leading universities in China and at international

BRAINPOWER CONGRESS 2023

ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Energy, Physics, Mathematics)

Development of Novel High-Performance Anode Materials for Sustainable Energy Storage

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 80%

Abstract:

Sustainable anode materials are gaining increasing attention in emerging energy storage applications. In this research, we demonstrated a self-healing conductive polymer (SHP) covering biomass-derived SiO_2/C and metal-organic frameworks (MOFs) with impressive morphology, designable molecular architecture, tunable functionality, and performance through a simple and fast method. For the SHP@SiO_2/C, the SHP conductive networks are composed of extensive Schiff base units that are repairable, functioning as dynamic crosslinking to heal their structures from volume expansion. Moreover, the novel MOF anode performs excellently in terms of electrochemical properties and battery performance. Also, the first-principles computations were used to reveal the stability and position of the Li intercalation and diffusion paths in the MOF structures. The research highlighted the development of green nanocomposites and MOF-based materials, an exciting area of research that has the potential to address some of the key challenges associated with lithium-ion batteries while also promoting sustainability and reducing environmental impact.

Rationales/Problem statements:

Lithium-ion batteries (LIBs) are widely used as state-of-the-art energy storage systems, especially in electric vehicles. Higher energy and power density are now being demanded by the marketplace, mainly dictated by the materials employed. Graphite is a

commonly used anode in commercial LIBs. However, it has a relatively low specific capacity, which cannot meet the demands of high-energy LIBs. Even though graphite has a high electrode/electrolyte interphase, is low-cost, and has an acceptable cycle life, its low operating voltage can cause lithium dendrites to grow, which can cause a cell short circuit. Because of the limitations of graphite, this has led to the exploration of innovative anode materials. Nevertheless, these materials also have their own challenges, such as volume expansion, dendrite formation, capacity fading, and safety concerns, which need to be addressed to enable their commercialization. Overall, developing innovative anode materials is an ongoing research focus in the field of LIBs.

Objectives:

- To develop a new type of advanced anode material, metal-organic network materials and a group of nanocomposite materials prepared from domestic wastes.
- To characterize the physical-chemical properties and electrochemical performance of synthesized anode materials and study the structural changes of anode materials by the synchrotron light technique.
- To develop and connect research networks in science and technology both nationally and internationally.
- To develop and create researchers and graduates to support cutting-edge technology, innovation, and other future technologies.
- To publish developed research in international academic journals listed in the ISI Q1 database with at least 2 papers.

Progress/Findings/Results:

There are several challenges associated with anode materials in LIBs, including capacity degradation, safety concerns, cost, and environmental impact. Importantly, developing more sustainable and environmentally friendly anode materials is a critical challenge for the industry. In this work, the use of biomass-derived green nanofillers (SiO_2/C) with self-healing conductive polymers and innovative isostructural dual-ligand MOFs has been illuminated as alternative anodes.

This research achieved success in developing an ecologically friendly and sustainable self-healing conductive polymers@SiO_2/C nanocomposite anode material for LIBs. *Streblus asper* leaves, a biomass waste, were not only used to produce carbon-based materials possessing conductive properties but also to contain self-assembled SiO_2 nanoparticles in the form of SiO_2/C. The SiO_2 nanoparticles could enhance the specific capacity of anodes. Then, they were introduced into a conductive polymer network with binder to function as mechanically robust and self-healing nanocomposites in conductive polymers@SiO_2/C. The unique properties and self-healing features of 3D conductive polymer network assemblies improve the conductivity of composites during the charging-discharging process. The material's self-healing property allows it to repair itself when damaged, potentially increasing the battery's life. Besides that, the carbon layer, in conjunction with the flexible networks, can be thought of as a cushion to prevent the expansion of SiO_2 microspheres. At a current density of 0.3C, this synthesized SA-PPy@Nano-SiO_2/C anode provides a high specific capacity of 756 mAh g^{-1} for 350 cycles, accounting for 99.7% of the theoretical specific capacity. At the high current of 1C (758 mA g^{-1}), a superior sustained cycle life of over 500 cycles was evidenced, with over 93% capacity retention. The research also highlighted the potential for this approach to be scaled up for commercial production, which could have a significant impact on the sustainability of the lithium-ion battery industry.

Moreover, metal−organic frameworks (MOFs) have become one of the most promising active materials in lithium−ion batteries (LIBs) due to their designable molecular architecture and tunable functionality. Herein, we report a series of isostructural three-

dimensional MOFs of divalent Mn (1), Co (2) and Zn (3), $[M^{II}_2(H_2O)_2(4,4'\text{-bipy})(mal)_2]$. The MOFs can be prepared by a facile microwave-heating technique within a few minutes. Investigations on electrochemical properties and performance as active materials for LIBs anodes showed that Co-MOF 2 has higher efficiency than the Mn and Zn congeners, with an excellent specific capacity of 732 mAh g^{-1} after 200 cycles, which distinguishes electrochemical performance in specific capacity and rate cycle performance over the previous MOF-based materials. First−principles computations were used to study the stability and position of the intercalated Li and Li diffusion paths in the MOF structures. Density functional theory (DFT) calculations were employed to investigate the electronic structures of the obtained MOFs, which were further used for constructing the band diagrams to better understand their structure−properties relations.

In summary, this study highlights the potential of utilizing conductive polymers@SiO_2/C green polymeric nanocomposite and innovative isostructural dual-ligand MOF anodes in an attempt to develop anodes for the subsequent production of LIBs and energy storage fields that are more environmentally sustainable.

Conclusion:

This research achieved success in developing a sustainable SHP@SiO_2/C nanocomposite using biomass as a raw material and novel isostructural dual-ligand MOF anodes for LIBs. Both materials demonstrate outstanding electrochemical achievement, particularly in terms of specific capacity and cycle stability. When compared to traditional anode materials, the synthesized materials have superior characteristics, are more environmentally benign, and are more sustainable because they can potentially be mass-produced with plenty of resources in a low-cost manner. Overall, this research reveals the promise of employing both synthesized anodes to develop more ecologically friendly anodes for the next generation of LIBs and energy storage fields.

Current Output:

- 1 original drafted manuscript
- 1 submitted manuscript

Challenges/Problems and Possible solutions:

There is no problem in this research.

Future plan:

SA-PPy@Nano-SiO_2/C anode will be prepared as anodes for LIBs. Then, these prepared electrodes will be assembled into a half-coin cell. After that, the battery performance of the fabricated coin-cells, including galvanostatic charge and discharge profiles, rate capability, and cycle stability, will be evaluated at room temperature. Cyclic voltammetry and electrochemical impedance spectroscopy will also be recorded at a constant room temperature. Finally, all data will be analyzed and discussed for manuscript writing, then the manuscript will be submitted to international academic journals listed in the ISI Q1 database.

Harnessing Solution Plasma for Electrical Energy Storage Materials

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Project duration: 1 Year, from 1 April 2023 to 31 March 2024

Current progress: 49%

Abstract:

The first 6 months of the project largely followed the plan outlined in the proposal. The conditions for solution plasma process (SPP) were optimized for the synthesis of reduced graphene oxide (rGO)/MnO_2 composite. To ensure an overall green process, rGO was prepared using ascorbic acid as a reducing agent, and no annealing process was used to post-treat the synthesized rGO/MnO_2 composite. Interestingly, we found that adjusting the precursor solution to pH 10 helped enhance the degree of MnO_2 formation on the surface of rGO nanosheets, which yielded increased electrochemical performance. The results demonstrate that using SPP provides an efficient, green approach for the preparation of nanomaterials such as rGO/MnO_2 composite for energy storage application. Filing for a petty patent based on this technique and drafting manuscripts are underway.

Rationales/Problem statements:

Nanomaterials increasingly plays an important role in wide-ranging applications, especially in energy storage sector. Graphene oxide (GO) and MnO_2-based materials perhaps represent one of the most studied nanomaterials, with various preparation methods reported to date. This project proposes a novel preparation method that is based on the use of solution plasma process to circumvent complex preparation steps and to offer an environmentally friendly approach. In our previous effort, we showed the viability to apply solution plasma in the synthesis of efficient energy storage materials based on MnO_2. In this work, the method is extended to cover composites involving reduced GO as a starting precursor, which is a normally difficult precursor for preparing metal composites in aqueous environment. A lab-scale prototype will also be developed to illustrate the potential of the solution plasma-synthesized composite and its promise for commercial prospect.

Objectives:

1. Design the synthesis of rGO/MnO_2 composites using solution plasma.
2. Study the use $KMnO_4$, $MnCl_2$, $MnSO_4$, and/or $MnCO_3$ as a starting precursor for the formation of MnO_2 in the composites via solution plasma.
3. Investigate the effect of annealing process at various temperatures and annealing time on electrochemical properties and performance of the composites synthesized.
4. Fabricate a lab-scale prototype of the supercapacitor based on rGO-MnO_2 composite prepared using solution plasma.

Progress/Findings/Results:

According to the cyclic voltammetry at the scan rate of 5 mV s^{-1} (Fig. 1), rGO yielded the specific capacitance of only 48 F g^{-1}, whereas rGO-MnO_2 produced the values of 73.8, 88.0, 97.2, and 81.1 F g^{-1} for the solution plasma treatment for 2, 6, 10, and 15 min, respectively. Thus, a 10 min-solution plasma treatment was used in subsequent experiments.

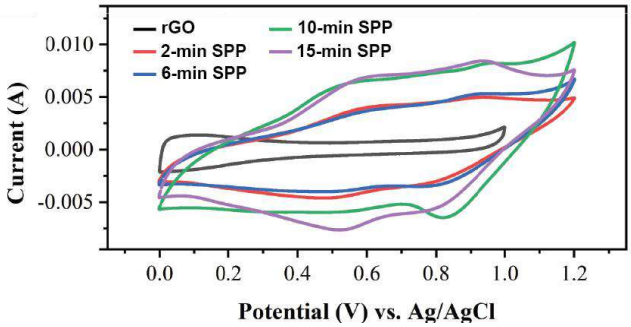

Fig. 1. Cyclic voltammograms for rGO-MnO_2 composites prepared using different durations of solution plasma.

Other experimental conditions that resulted in optimal synthesis of rGO-MnO_2 include a 1:2 ratio by mass of rGO to MnO_2, as well as 1.4 kV in voltage, 0.9 kHz in frequency, and 2 μs in pulse width for the solution plasma discharge. In addition, we found that adjusting the pH to 10 of the precursor solution prior to SPP also resulted in greater degree of MnO_2 nanoparticles formed on the surface of rGO (Fig. 2). In fact, based on the cyclic voltammetry and galvanostatic charge/discharge characterizations, such increased deposition of MnO_2 on rGO also led to higher electrochemical performance of the composite.

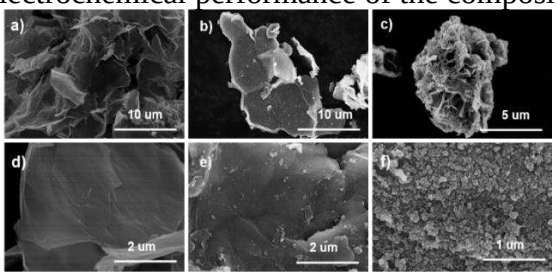

Fig. 2. FE-SEM images of (a, d) pristine rGO, (b, e) rGO-MnO_2, and (c, f) rGO-MnO_2 with adjusted pH.

Conclusion:

The first 6 months of the project closely followed the plan outlined in the proposal. The setup for the SPP has been optimized for the synthesis of rGO-MnO_2 composites. Electrochemical and physical characterizations now confirmed that the method is viable for the preparation of the Mn-based materials for energy storage application.

Current Output:

Filing for a petty patent as well as drafting manuscripts are in the process.

Challenges/Problems and Possible solutions:

The challenges encountered are mostly experimental in nature, which, so far, could be resolved by the collaboration among the project members.

Future plan:

Different Mn precursors will be investigated, and optical emission spectroscopy will be performed to gain more information about mechanism for the formation of MnO_2 during the solution plasma process.

Study and Development of Porous Nanofibers, Graphene Oxide Quantum Dot Nanofiber Composite, and Metal Doped Graphene Oxide Quantum Dot Nanofiber Composite for Carbon Dioxide Reduction and Capture

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 60%

Abstract:
Quantum Dots (QDs), are exotic nanostructures with tunable quantum efficiency, size range, and fluorescence emission that can be employed for diverse applications such as semiconductors, supercapacitors, photodetectors, photodiodes, solar cells, fuel cells, bioimaging, catalysis, sensors, and theranostics. However, the hazardous reaction conditions and the toxic chemicals used for the synthesis and stabilization of the QDs used in the above methods make them unsuitable for biomedical applications. Biogenic approaches for the fabrication of QDs are attractive. Diverse phytochemicals present in the plant extract may play a critical role in the synthesis, shape evolution, and stabilization of the biogenic QDs are also covered. In view of the background, the following report gives an elaborate account of the synthesis of carbon quantum dots (CQDs) using *Syzygium samarangense* popularly known as Java apple. The CQDs were characterized and will be used further to incorporate within electrospun polymeric nanofibers for carbon dioxide reduction and capture.

Rationales/Problem statements:
Tremendous increase in the green house gases has led to global warming which is affecting the nature and health. The increase in the carbon dioxide in the atmosphere at an alarming rate has emphasized on the need to develop sustainable strategies for carbon capture. Hence, nanotechnology driven solutions are being designed as it is thought to be rapid, efficient and advanced. Extensive efforts to develop composite nanostructures using polymers, metal, metal-oxide and other nanomaterials aim to capture carbon dioxide from the atmosphere and reduce air pollution. Although there are various methods for biological synthesis of carbon quantum dots (CQDs), *Syzygium samarangense* has not been explored yet. Hence, it would be interesting to incorporate the phytogenic CQDs into electrospun polymeric fibers composed of polystyrene (PS)/polyethylenimine (PEI). This advanced membrane with desired morphological and functional properties may play a significant role in carbon dioxide reduction and capture.

Objectives:
(1) Synthesis and characterization of the carbon quantum dots.
(2) Synthesis of polymer nanofiber composite using electrospinning and their characterization.
(3) Determination of carbon dioxide reduction and capture efficiency.

Progress/Findings/Results:

Synthesis of CQDs:
The fresh Java apples were used for the preparation of the plant extract. The stepwise processing of the fruits was carried out eventually getting the pure fruit juice which was used for further CQDs preparation. The CQDs were synthesized by direct hydrothermal treatment of the fruit juice at 180 °C for 36 h. Then the resulting CQDs were collected by

filtration with a 0.22 µm membrane that showed brown colour in visible light while it exhibited bright fluorescence under UV light. The use of Java apple juice as a natural precursor and low synthesis temperature allowed for the highly scalable and sustainable synthesis of CQDs.

UV-visible spectroscopy:

An aqueous dispersion of the CQDs was highly stable without any sign of precipitation even after four months. On irradiation with 365 nm UV light, the aqueous solution of CQDs showed an intense greenish blue color indicating its potential in the optoelectronic and biomedical fields. The UV-visible spectroscopy revealed a sharp peak at 283 nm which indicated the successful synthesis of the CQDs from the plant extract. Further, the UV-Vis absorption data was fitted by Tauc's formula for direct band gap evaluation.

FTIR analysis:

The Fourier transform infrared (FTIR) spectrum showed the presence of significant surface functional groups. The merged peaks at ~1595 cm−1 were assigned to C=O and C=C stretching in the conjugated structure. The C=O and C-O stretching vibrations at ~1595 cm−1 and ~1405 cm−1, respectively, indicate the presence of oxygenated carboxyl and hydroxyl functional groups. Furthermore, the intense band at ~3393 cm−1 can be assigned to typical –O-H stretching vibrations. The doublet at ~2937 represents C-H stretching. The broad band at ~618 cm−1 was ascribed to =C–H stretching.

TEM analysis:

The morphology and microstructure of the CQDs were investigated using transmission electron microscope (TEM) analysis. Typical TEM image exhibited that the CQDs were nearly monodispersed and almost spherical. The CQDs exhibited a narrow size distribution in the range of 4–7 nm.The CQDs were highly crystalline with a d-spacing of 0.24 nm.

Conclusion:

Biogenic CQDs with attractive morphological and optical properties hold great promise for biomedical, environmental, and industrial applications. The route for synthesis is rapid, efficient, and environmentally benign where the generated CQDs are highly fluorescent and biocompatible. The smaller size of the biogenic CQDs makes them attractive for easy uptake and elimination after activity from the cells. However, in order to ensure their clinical translatability, thorough toxicity studies along with pharmacokinetic and pharmacodynamic investigations are warranted. Moreover, the various synthesis parameters like fruit juice concentration, reaction time, temperature, and pH, should be carefully optimized to improve scalability that would ensure higher yield and decrease the production cost. Incorporating the biogenic CQDs into polymeric nanofibers can yield significant properties for ideal carbon dioxide reduction and capture. Thus, with a systematic approach coupled with global R&D and commercialization efforts, biogenic CQDs have a high probability to revolutionize the future of environmental nanotechnology.

Current Output:

During the period 2 manuscripts were published in Frontiers in Chemistry (**Impact Factor : 5.5; Q1 category journal**), and 10 book chapter manuscripts were submitted and accepted in books from reputed publishers like Elsevier, CRC Press, Taylor and Francis, De Gruyter, and Springer. Data was also presented in 2 international conferences in Philippines and Indonesia.

Publication in Q1 category International Journal:

Ghosh S, Nandasana M, Webster TJ, **Thongmee S** (2023) Agrowaste generated biochar for the sustainable remediation of refractory pollutants. Frontiers in Chemistry. 11:1266556.

Ghosh S, Turner RJ, **Thongmee S** (2023) Editorial: Biofabrication of nanostructures for environmental, agricultural, and biomedical applications. Frontiers in Chemistry. 11:1283676.

Challenges/Problems and Possible solutions:

Challenges:

1) Achieving the accurate viscosity of the polymer mixture for efficient electrospinning is challenging.

2) Getting the desired shape, structure, and surface feature of the electrospun polymeric fiber will be critical for its catalytic activity.

Possible solutions:

Parameters such as polymer concentration, the tip-to-collector distance, voltage range, feed rate of the solution, and rotation speed of the metallic cylinder for collection will be optimized to achieve desired properties of the polymeric fiber during the electrospinning process.

Future plan:

Incorporation of the phytogenic CQDs into the polymeric fibers developed using electrospinning will be the next target. The CQDs impregnated fibers will be characterized using scanning electron microscopy. The carbon dioxide reduction and capture efficiency of the novel nanocomposite fiber will be evaluated.

Quantum Electron Transport in van der Waals Heterostructures

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 60%

Abstract:
At the forefront of 2D material research is the creation of van der Waals heterostructures in which various 2D materials are vertically stacked layer-by-layer to form new artificial materials with atomic level precision. The research objective of this project is to explore the quantum electronic properties of these van der Waals heterostructures with especial emphasis graphene to study quantum transport phenomena such as quantum interference, ballistic transport, and quantum Hall effect. The insight gained from this project has far-reaching implications for engineering novel quantum devices at nanoscale. We plan to achieve the proposed research objective through the nano-fabrication, and transport measurement. Undergraduate and graduate students are involved in all phases of experiment from device design, nanofabrication, and cryogenic transport measurement to promote the next generation of scientists to take on challenging problems.

Rationales/Problem statements:
Van der Waals heterostructures are composed of atomically thin 2D materials, such as graphene and transition metal dichalcogenides which have tunable electronic properties. By stacking different layers, researchers can engineer the electronic band structure to achieve a wide range of electrical characteristics, from semiconducting to metallic behavior. The interactions between different 2D materials in heterostructures can lead to emergent phenomena that are not present in individual layers. For example, stacking two monolayer graphene can create a superconductor. Quantum mechanics becomes increasingly relevant at the nanoscale and vdW heterostructures offer a platform for studying quantum transport phenomena. Researchers can investigate the behavior of electrons and other charge carriers in these materials under extreme conditions, such as low temperatures and strong magnetic fields. Research on quantum transport in these structures contributes to a deeper understanding of condensed matter physics and quantum mechanics, providing insights into the behavior of electrons at the nanoscale.

Objectives:
We will explore the quantum electronic properties of van der Waals heterostructures and build upon this understanding to engineer novel quantum devices. Specifically, we plan to investigate quantum interference, ballistic transport, and quantum Hall effect in few-layer graphene and twisted bilayer van der Waals heterostructures. In addition, we will establish nanofabrication process suitable for instruments available in Thailand and low temperature laboratory for measurement of quantum electronic devices.

Progress/Findings/Results:
We investigate magnetotransport properties of tetralayer graphene encapsulated by hexagonal boron nitride to form van der Waals heterostructures. In our devices, the dry transfer technique is employed to assemble the heterostructures. Graphene and hexagonal boron nitride are obtained from mechanical exfoliation from natural graphite and high-purity hexagonal boron nitride crystal, respectively. We use electron-beam lithography to define etch masks and etch the heterostructures in CHF_3/O_2 plasma. Edge contacts are defined by an additional step of electron beam lithography and formed by sputtering 80-nm Mo or

Cr/Au. The standard lock-in technique with the excitation frequency of 17~Hz is used to investigate magnetotransport properties. All the measurements in this work are performed at 2.4 K. We employ a superconducting magnet with a maximum field of 7 T to measure electric signal at finite magnetic field.

The band structure of Bernal-stacked tetralayer graphene consists of two massive subbands with different effective masses. Under a finite displacement field, we observe valley splitting of Landau levels (LLs) only in the light-mass subband, consistent with a tight-binding model. At low density, we find unexpected magnetoconductance oscillations in bulk gaps which originate from a series of hybridizations between electron-like and hole-like LLs due to band inversion in tetralayer graphene. In contrast to a trivial LL quantization gap, these inverted hybridization gaps can lead to a change in number of edge states which explains the observed oscillations.

In addition, we have successfully designed, fabricated and measured an L-shaped device to investigate the impact of crystal orientation on transverse magnetic focusing peaks. Given the inherent trigonal warping of the Fermi surface in tetralayer graphene, influenced by the hopping parameter gamma3, transverse magnetic focusing manifests distinct variations depending on the crystal orientation. Trajectories of electrons corresponding to Fermi surfaces in Fig. 6.2 (b) and (d) are illustrated, showcasing the diverse paths electrons can take when entering graphene from different directions. The resulting electron focus occurs at caustic lines, distinctly visible as denser lines. These findings contribute to a nuanced understanding of the interplay between crystal orientation and transverse magnetic focusing peaks in tetralayer graphene, shedding light on the intricate quantum phenomena at play.

Conclusion:

We have successfully completed the measurement of ballistic transport in tetralayer graphene using transverse magnetic focusing. These measurements have provided compelling evidence of trigonal warping on the Fermi surface. Notably, for the first time, we have demonstrated that the focusing peaks are dependent on the crystal orientation of the sample. Our team is currently in the data analysis phase and preparing a manuscript for publication.

Current Output:

1 Publication in Physical Review B (Tier 1). Another publication is in preparation.

Challenges/Problems and Possible solutions: -

Future plan: We anticipate the completion and subsequent submission of our manuscript for review within the forthcoming two months. Our experimental pursuits will encompass the investigation of ballistic transport in graphene, focusing on Moiré superlattices, and the examination of the quantum Hall effect in tetralayer graphene. A procedural enhancement involves the transition from a silicon (Si) back gate, the present substrate, to the adoption of graphite for back gating. This pragmatic alteration is undertaken with the objective of optimizing the experimental platform, foreseeing an improved resolution in discerning splittings within the zeroth Landau level in tetralayer graphene.

Experimental and Theoretical Studies of Ti_3C_2Tx MXene Quantum Dots for Gas Sensing Application

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 80%

Abstract:

In the first 6 months of the progress report, we have successfully achieved the planned. The work has focused on the synthesis of MXene QDs using Ti3C2Tx MXene and the successful synthesis of MXene QDs materials. The initial materials used for synthesizing MXene QDs included Ti_3C_2Tx MXene and Ti_3AlC_2 MAX phase. The structures and properties of these three materials were studied and applied for sensor applications using techniques such as SEM, FE-TEM, XRD, XPS, and EDX. In the theoretical study of MXene QDs materials, a 3-D model was designed using computer simulations, and a bilayer MXene QDs material was designed. Furthermore, a model was developed by adding Tx groups to the edges of the bilayer MXene QDs material. In this progress report, the research project has yielded international publications and has been published in ISI/Scopus-indexed journals with a high impact factor (Q1) for two publications.

Rationales/Problem statements:

Objectives:

1. To synthesis the MXene quantum dots materials as sensing materials in gas detection.
2. To study the MXene quantum dot materials in theoretical using the principles of quantum mechanics of the SCC-DFTB method to identify the target gas
3. To produce the MXene quantum dots sensor for detection of target gas based on theoretical calculations.

Progress/Findings/Results:

Synthesis of Ti_3C_2Tx MXene quantum dots (Ti_3C_2 MXene QDs). First, 40 mg of Ti_3C_2Tx MXene powder dispersed in 10 mL of nitric acid (5 M), which was then put in an oil bath and reacted at a constant temperature of 100ºC for 24 h. After cooling to room temperature, the solution was poured into 30 mL of ice water and the pH of the solution was adjusted to 7 using NaOH (1M). After centrifugation, the obtained sediment was redispersed in 40 mL of ultrapure water to obtain Ti_3C_2Tx MXene solution. After synthesizing Ti_3C_2 MXene QDs, structural analysis using the FE-TEM technique was conducted to confirm their size. The Ti_3C_2Tx QDs were found to have a size ranging from 4 to 24 nm, with an average size of approximately 12.42 nm. The 3D model of Ti_3C_2Tx MXene QDs incorporates Tx atoms on the Ti_3C_2Tx MXene QDs surface, comprising oxygen (O), hydroxyl (OH), and fluorine (F) groups. Modeled in bilayers of the Ti3C2Tx MXene QDs consists of 6 Ti atoms and 4 C atoms.

In this project, there is an interest in further synthesizing nanocomposite materials

using titanium carbide MXene (Ti_3C_2Tx MXene) mixed with other materials. Graphene oxide (GO), copper oxide (CuO), and zinc oxide (ZnO) materials were incorporated into Ti_3C_2Tx MXene and synthesized using the hydrothermal method to be a gas sensor. The Ti_3C_2Tx MXene/GO/CuO/ZnO nanocomposite gas sensor exhibited the best NH_3 gas sensor. The effects on the weight ratios of Ti_3C_2Tx MXene/GO/CuO/ZnO were also investigated, and the optimal Ti_3C_2Tx MXene/GO/CuO/ZnO weight ratio was determined to be 9:1:5:5. The optimal Ti_3C_2Tx MXene/GO/CuO/ZnO based gas sensor showed a high response of 96% at 200 ppm of NH_3, humidity independence in the range of 30-70% RH, low limit of detection of 4.1 ppm, and high selectivity to NH_3 over several gases/VOCs.

Moreover, this project has been interesting a novel fabric-based piezoresistive force sensor array based on titanium aluminum carbide MAX phase (Ti_3AlC_2) mixed with PEDOT:PSS to be nanocomposite. The fabricated force sensor exhibits an ultrahigh sensitivity up to 1.51 N^{-1}. The fabric-based piezoresistive Ti_3AlC_2/PEDOT:PSS force sensor shows a wide force detection range of 0-200 N and fast response and recovery times of 0.4 s and 0.08 s, respectively.

Conclusion:

In this research, the Ti_3AlC_2 MAX phase and Ti_3C_2Tx MXene are the initial material to synthesize the Ti_3C_2Tx MXene QDs. Their structures and various properties were studied for potential applications as sensors. The Ti_3C_2Tx MXene was doped with metal oxide nanoparticles, exhibits enhanced gas detection performance. Additionally, during the research, Ti_3AlC_2 MAX phase was employed to create a force sensor, improving measurement efficiency by incorporating the conductive polymers of PEDOT:PSS. The theoretical investigation of the Ti_3C_2Tx MXene QDs, simulation design was conducted to model the structure of a bilayer Ti_3C_2Tx MXene QDs material.

Current Output:

1. Y. Seekaew, S. Kamlue, and C. Wongchoosuk, "Room-Temperature Ammonia Gas Sensor Based on Ti_3C_2Tx MXene/Graphene Oxide/CuO/ZnO Nanocomposite," ACS Appl. Nano Mater. 2023, 6, 9008−9020.
2. T. Seesaard and C. Wongchoosuk, "Fabric-based piezoresistive Ti_3AlC_2/PEDOT:PSS force sensor for wearable E-textile applications," Organic Electronics 122 (2023) 106894.

Challenges/Problems and Possible solutions (if any, Maximum 100 words):

- No.

Future plan:

This research project will continue to investigate the theoretical aspects of Ti_3C_2Tx MXene QDs. The focus is on studying the theoretical aspects of Ti_3C_2Tx MXene QDs that involve combining gas molecules with Ti_3C_2Tx MXene QDs to determine the optimal positions and distances for the most effective reaction and subsequent adsorption energy. After that, the gas sensor of the synthesized Ti_3C_2Tx MXene QDs will be tested against the target gas.

On the Role of White Dwarfs in Close Binary Systems and Evolved Planetary Systems

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 65%

Abstract:
We establish the long-term light curves of three debris-transiting systems ZTFJ032833.52-121945.27 (ZTFJ0328-1219), ZTFJ092311.41+423634.16 (ZTFJ0923+4236), and WD1145+017. Combining archival photometric observations from multiple large-area surveys spanning the past 17 years, we detect long-term variability in the light curves of these systems. In addition, we obtained high-speed photometry of these three systems using 2.4 m-Thai National Telescope (TNT). The time-series photometry exhibits vast variations in the level of transit activity, both in terms of numbers of transits, as well as their shapes and depths, and these variations correlate with the overall brightness of the systems. We suggest that a substantial fraction of all white dwarfs exhibiting photospheric metal pollution from accreted debris host close-in planetesimals that are currently undergoing disintegration.

Rationales/Problem statements:

(a) White dwarf in close binary systems

Despite its great importance, close binary star evolution is still poorly understood. Among compact binaries, Cataclysmic Variables (CVs) are the best tracers of close binary evolution. However, one of the factors complicating the use of these stars for binary evolution studies, is that samples of known CVs are heavily biased towards long period systems, as these are the brightest, bluest and most variable CVs. In order to solve this problem, we will search for the faintest CVs, to properly characterise the faint, but dominant, population of CV.

(b) Evolved planetary systems

The vast majority of all known planet-hosting stars, including the Sun, will eventually evolve into red giants, lose a large fraction of their mass as planetary nebulae, and then become white dwarfs, gently glowing for many billion years. The study of these evolved systems provides a window into the architecture of long-lasting planetary systems and the properties of planets that is complementary to the insight that can be gained from exo-planets orbiting main-sequence stars.

Objectives:

- Search/follow-up for faint/short CVs to slove the discrepancy between the observations and standard models of close binary evolution.
- Search/follow-up for evolved-planetary systems to understand the final state of evolution of Solar-like systems.

Progress/Findings/Results:

We retrieved the sparse, long-term photometry of ZTFJ0328-1219, ZTFJ0923+4236, and WD1145+017 from 2006–2023 obtained by CRTS, ASAS-SN, ATLAS, and the ZTF Data Release. In addition, during 2016–2023, we obtained high-speed photometry of these systems using the ULTRASPEC mounted on the 2.4m TNT.

- **ZTF J032833.52-121945.27**

The CRTS light curve of ZTFJ0328-1219 displays a slight dimming in 2011. The seasonal average brightness continued to drop in the following years, ending up ~0.3 mag fainter in

2014, compared to the first season in 2006, and brightening again. The TNT light curves display a mix of narrow, well-defined transit features and broader, complex absorption structures, with no constant "out-of-transit" stretch. As such, it is conceivable that the flux from the white dwarf is attenuated at all orbital phases, and hence the star is dimmed overall with respect to its intrinsic brightness consistent with the fact that the latest long-term photometric data shows the brightness level of ZTF J0328-1219 still ~ 0.1 mag fainter than during the earliest available survey data.

- **ZTF J092311.41+423634.16**

The long-term light curve of ZTF J0923+4236 demonstrates that the system has been undergoing fading events on time-scales of months, with an amplitude of up to ~1 mag over the past 17 years. The TNT light curves obtained in December 2020, when the system was near its faintest state, display rapid variability on time scales of a few minutes. In March 2021, the system was in a slightly brighter state, and the light curves are totally lack of any transit activity. Further observations obtained in March 2022, again at an intermediate brightness level, show mild variability on time scales of ~1 h. Whereas the larger transit activity observed in December 2020 results in an overall dimming of the average brightness of the white dwarf, the long-term light curve shows an overall fading of nearly one magnitude, suggested the transit activity correlates with an overall dimming of the system.

- **WD1145+017**

The long-term light curve of WD1145-017 shows that the overall transit activity reached a maximum around 2017. In the following years, the transit activity decreased, with the average transmission varying from 2019–2021 between close to zero and five per cent. After that, the average transmission remained at very high levels of about one per cent. The TNT light curves obtained from 2015–2023 illustrate the change in the transit activity of the system, both in terms of morphology of the individual transits and the overall light curve. During very active periods (2016–2017), there is hardly any segment of the light curve that is not affected by transits. In 2018 and 2019, the deep and sharp transits changed into broader and shallower absorption structures. Our latest data obtained in 2022 and 2023 exhibits nearly no transit activity, apart from one single short transit detected on 2023 February 20. Such sharp transits are likely related to dust freshly released from a fragment either undergoing a collision with another solid body, or suffering structural stressed due to tidal effects.

Conclusion

We detect long-term variability in three white dwarfs that are known to exhibit transits from planetary debris, and at least in two cases, the long-term changes in brightness correlate with the level of activity detected in time-resolved photometry. Our study highlights the potential of a joint analysis of the nearly two decades of large-area survey photometry as a novel approach in identifying white dwarfs that exhibit irregular variability.

Current Output:

1st year: "Long-term photometric monitoring and spectroscopy of the white dwarf pulsar AR Scorpii", Monthly Notices of the Royal Astronomical Society (Q1) (Impact Factor = 5.235), Volume 516, Issue 4, November 2022, Pages 5052–5066

2nd year: "Long-term variability in debris transiting white dwarfs" Monthly Notices of the Royal Astronomical Society (Q1) (2022 Impact Factor = 4.8) (submitted)

Challenges/Problems and Possible solutions: -

Future plan:

In the 3rd year, we plan to study the systems that related to final state of CV evolution and/or characterise the evolution of an evolved planetary system.

Development of the Galactic-outflow Model by Computer Simulation to Explain and Predict the Large-scale Outflow in Observations

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 70%

Abstract:
We investigate the influence of Toomre's Q parameter on the bar-forming dynamics and the subsequent evolution of Maclaurin dis. We include the effect of velocity dispersion, as the pressure potential, into the effective potential with the gravitational potential, becoming the effective potential. This effective potential hypothesis can describe the Q-dependences of the angular and the epicyclic motions of the bar-forming processes and the established bars reasonably well provided that $Q > 1$. With the inclusion of the halo into the system, disks are more prone to the bar formation as seen by the elevated critical Q than that for the disk without halo. This is attributed to the differential rotation that builds the unstable non-axisymmetric spiral modes more effectively which are the ingredients of bar instability.

Rationales/Problem statements:
Despite the fruitful numerical results, the dependence of the disk and bar kinematics on the Toomre's Q parameter has not drawn much attention. How Q is involved in the detailed disk dynamics that resulted in the barred state remained to be investigated. We hypothesize that the velocity dispersion, which can be constructed from any model of Q, gives rise to the pressure and it introduces the additional pressure force in the disk that directionally opposes the gravitational force. Therefore, we formulate the effective potential hypothesis to describe the systems of various Q.

Objectives:
The central interest of this work is on how well we can describe the role of Q in the disk dynamics and how it influences the bar formation as well as the resulting bar properties. We will develop the theoretical model of the disk dynamical structure based on that assumption. We also examine if the presence of halo affects the stability criterion for the disk with the same surface density and Q profile but without halo. We also resolve the puzzle of the bar formation in hot disks. To do so, we modify the core so that it becomes elliptical.

Progress/Findings/Results:
It turns out that if $1 < Q < 1.5$, the disks are bar-unstable as the bar amplitude grows from the initial state before the growth is put to an end when the bar amplitude reaches the maximum and remains high afterwards. The effective epicyclic frequency explains reasonably well the measured radial oscillation frequency of nearly circular orbit particles, but it slightly underestimates the measured values but the decrease with Q is evident. It turns out that not only the disk angular frequency that is shifted by finite Q, but the epicyclic frequency is also shifted accordingly. Considering the epicyclic frequency at the different times, the epicyclic frequency of the fully formed bar is found to be lower than the radial oscillation frequency in the initial phase. The decline is modest if $Q < 1$. We observe the bar oscillation frequency as a function of Q that keeps the same tendency with the theoretical line. It can be deduced that the radial action transfer from the bar to the outer component that rotates more slowly is possible. When the halo is present, the disk is bar-unstable although

Q exceeds 1.65: it is somewhere between 2−2.25 depending on the halo type. That value was sufficient to stabilize the isolated disk. The elevation of critical Q is attributed to the differential rotation as it engenders the swing amplification. We compare our stability test with the OP and ELN criteria of bar stability. We numerically calculate both indicators for our disk-halo initial states and find that the critical values slightly differ. This is because the disk family that we adopt differs from those employed in the original analyses. Finally, we capture the strong breakthrough bars in some cases with elliptical disk center. Some weaker bars are also spotted.

Conclusion:

Bars can be developed when Q < 1.5. When Q is lower Q, a more rapid bar formation and the spiral structure takes place. On the contrary, a high-Q disk leads to the gentle bar formation with no visually detectable spiral pattern. With a closer look, the angular frequency of the linearly unstable two-armed modes, the bar pattern speed, the radial oscillation frequency of the particles in the ear stage, and the bar epicyclic frequency correlate with the effective frequency that is a function of Q if Q > 1. With
the presence of halo, the critical Q is significantly shifted upward.

Current Output:

1 publication in a Q1 journal and 1 article under review.

Challenges/Problems and Possible solutions: -

Future plan:

We proceed on the in-depth investigation of the center of the system, via the measurement of the phase-space density. That problem is studied using the one-dimensional counterpart due to its simplicity. The systems are evolved to the Quasi-Stationary States (QSSs) with a reliable code, the heap-based algorithm. We conclude with the dependence of the core phase-space density on the particle number N and its varying agreement with the Lynden-Bell theory.

Effects of Doping and Codoping to Capacitive Property of TiO_2- and $ATiO_3$- based Ceramics: Mathematical Modeling, Machine Learning and Experiments

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Project duration: 1year, from 1 August 2022 to 31 July 2023

Current progress: 98.2 %

Abstracts:

This work consists of three sub-research projects outlined as follows: In Sub-project 1, we utilize density functional theory to investigate electronic characteristics, including the total energy, of various metal ions incorporated into TiO_2 and $ATiO_3$ ceramics. Additionally, we calculate total energies for different oxygen vacancy positions within these structures. Sub-project 2 employs the results from Sub-project 1 as input data for machine learning to predict total energy values for the crystal structures of these ceramics, while also pinpointing the locations of metal dopants within the structures. We optimize our process to achieve the highest accuracy in results. Sub-project 3 focuses on synthesizing TiO_2 and $ATiO_3$ ceramics doped with metal ions and analyzing their structural, dielectric, electrical, and chemical properties. These investigations are crucial for understanding how these properties are affected by the synthesis method and the distribution of metal ions within these ceramics.

Rationales/Problem statements:

The advancement of modern technology, particularly electronic technology, holds significant importance in both the industrial sector and contemporary human life. Capacitors emerge as pivotal components within electrical circuits, playing a critical role in the development of miniaturized and lightweight electronic devices. To enhance the efficiency of these capacitors, it becomes crucial to advance the development of the materials used within them. Dielectric materials take a prominent role among the components found within capacitors. These materials must meet specific criteria established by the Electronics Industries Association of America (EIA), which include: (1) maintaining a high dielectric constant value (ε') exceeding 1000, (2) exhibiting minimal dielectric loss at a 1000 Hz frequency, below 0.03 (tanδ), and (3) demonstrating minimal variations in dielectric constant with temperature, in accordance with the EIA standard.

Objectives:

1. To enhance the capacitive and electrical characteristics of TiO2 and ATiO3 ceramics through doping or co-doping with metal ions.
2. To investigate the impact of various synthesis methods and the co-doping of metal ions on the microstructure, electrical properties, and dielectric properties.
3. To explore the mechanisms underlying the remarkable giant dielectric constant and low loss tangent in TiO2 and ATiO3 ceramics through mathematical simulation and machine learning.
4. To expand the research community in the field of energy storage materials.

Progress/Findings/Results:

Our study explores the dielectric and electrical properties of various elements doped $ATiO_3$ and TiO_2 ceramics. Investigating ceramics like $Li_{1/2}Sm_{1/2}Cu_3Ti_4O_{12}$ revealed high dielectric constants and low loss tangents, indicating potential for electrical applications. DFT analysis identified ion accommodation and oxygen vacancy effects, attributing colossal dielectric response to internal barrier layer capacitor models. Sintering $Na_{1/2}Y_{1/2}Cu_3Ti_4O_{12}$ ceramics at lower temperatures yielded exceptional dielectric permittivities and reduced loss tangents. DFT analyses tracked ion substitutions, emphasizing improved grain boundary responses and consequent enhancements in electrical performance. We synthesized $Li_{1/2}Y_{1/2}Cu_3Ti_4O_{12}$ ceramics with high dielectric constants and low loss tangents, observing diverse oxidation states related to oxygen vacancies. The presence of an internal barrier layer capacitor significantly contributed to the remarkable dielectric properties. Studying $Na_{1/2}Y_{1/2}Cu_3Ti_{3.975}Ta_{0.025}O_{12}$ (NYCTTaO) ceramics under varied sintering conditions showed a strong dependence on grain boundaries, affecting dielectric response and electrical properties. Internal barrier layer capacitor effects were key contributors to the observed behaviors. The impact of sintering conditions and doping levels in W^{6+}-doped TiO_2 ceramics revealed improved dielectric properties with higher doping concentrations and sintering temperatures, attributing giant dielectric response to interfacial polarization. Co-doping Tb and Nb ions into TiO_2 ceramics significantly enhanced dielectric properties. The ceramics exhibited temperature-stable dielectric responses and low loss tangents, owing to intrinsic defect clusters and the internal barrier layer capacitor microstructure. Examining Ni^{2+} and Nb^{5+} co-doped TiO_2 ceramics revealed a complex interplay of defect dipoles and barrier layer capacitor effects, impacting dielectric response. Optimizing doping concentrations led to high permittivity and low loss tangent at room and elevated temperatures.

In summary, our investigations into various doped ceramics underscore the intricate relationship between structural modifications, defect formations, and the resulting dielectric properties. Understanding these complexities aids in tailoring ceramics for enhanced electrical applications.

Conclusion:

Our exploration of metals doped and co-doped $ATiO_3$ and TiO_2 ceramics unveils their diverse electrical properties. Investigations into various ceramics, such as $Li_{1/2}Sm_{1/2}Cu_3Ti_4O_{12}$, $Li_{1/2}Y_{1/2}Cu_3Ti_4O_{12}$, $Na_{1/2}Y_{1/2}Cu_3Ti_4O_{12}$, Tb and Nb co-doped TiO_2, Ni^{2+} and Nb^{5+} co-doped TiO_2, W doped TiO_2 and $Na_{1/2}Y_{1/2}Cu_3Ti_{3.975}Ta_{0.025}O_{12}$, reveal high dielectric constants and low loss tangents, signaling promising dielectric prospects. Manipulating sintering conditions and doping levels has been found to improve these properties. DFT analysis revealed ion accommodation and oxygen vacancy formation driving colossal dielectric responses. Our study clarifies how structural modifications and defects influence dielectric behavior in these ceramics for advanced electrical applications.

Current Output:

1. Researchers in the field of energy storage materials: 5 Researchers.
2. Prototypes: 4 Prototypes.
3. Petty Patent: 1 Petty Patent.
4. Body of knowledge: 10 Bodies of knowledge.
5. Research Connections: 3 Universities.
6. Publications: 7 Q1 papers and 1 manuscript under revision.

Challenges/Problems and Possible solutions: -

Future plan:

The results from Machine Learning prediction might be used to investigate the defects inside various dielectric materials.

The Development of Mathematical Models and Optimization for Neural Networks Learning Process and Applications

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Project duration: 1 year, from 1 August 2022 to 31 July 2023
Current progress: 70%

Abstract:
In this project, we develop some new mathematical models of training frameworks of classifications and regressions via large-scale machine learning problems and neural networks. Under the knowledge of the convex optimization, we propose optimization iterative methods and analyze some sufficient conditions on the corresponding learning rates so that the convergence results for the methods are guaranteed. It is worth noting that the ideas and knowledge concerning both algorithms and convergence analytic frameworks have been applied in developing mathematical programs and web applications for predictions of both discrete and continuous time-series datum.

Rationales/Problem statements:
Artificial intelligence emerges nowadays as one of the most important issues in responding to human needs. We desire user-friendly models that are accurate and convenient to use. Machine learning arises as a fundamental training framework for obtaining a parameterized model to predict data with the goal that the model makes accurate predictions on newly unseen data. The standard machine learning for training the models is typically formulated as additive optimization problem of the sum of the loss function associated with the data point. The mentioned structure covers not only regressions and support vector machines which are typically utilized, but also deep neural networks which are more complicated in general. A key challenge is that the number of data points can be extremely large because the data sets nowadays are normally collected in multiple cores; moreover, the dimension of data points involving features can be large as well.

Objectives:
To develop optimization algorithmic frameworks for the purpose of speeding up and improving the accuracy when training the machine learning models. To propose distributed optimization methods for solving large-scale additive optimization problems of the sum of the loss function associated with the data points. To analyze some sufficient conditions on the corresponding learning rates and convergence results of the proposed methods. To apply the theoretical knowledge to develop mathematical programs and web applications for the predictions of both discrete and continuous time-series datum.

Progress/Findings/Results:
We have discovered new theoretical knowledge concerning both algorithmic and convergence analytic frameworks of the proposed distributed optimization models. More precisely, we proposed in the published papers the considering of large-scale additive

optimization problems in which the objective function is the sum of a large number of convex nondifferentiable loss functions. Based on the machine learning and neural networks, we assumed that each loss function is specifically written as the sum of two convex nondifferentiable functions in which one function (loss function) is appropriate for the subgradient method and another one (regularizer) is not. We proposed a distributed optimization algorithm based on the subgradient and proximal methods. The proposed method is also governed by an asynchronous feature that allows time-varying delays when computing the subgradients. We proved the convergences of function values of iterates to the optimal value. We applied the presented theoretical knowledge to develop mathematical programs in solving the binary classification problem via support vector machine learning. As a consequence of the obtained theoretical frameworks and mathematical programs, we also proposed web applications for binary classification via support vector machine learning and continuous time-series regression via deep neural network as prototypes corresponding to the outcomes of this research project.

Conclusion:

In this project, we have developed some new mathematical models of training frameworks of classifications and regressions via large-scale machine learning problems and neural networks. We have proposed optimization iterative methods and analyze its convergence results. The ideas and knowledge of the proposed algorithms and convergence frameworks have been applied in developing mathematical programs and web applications for classification and regression problems of both discrete and continuous time-series datum.

Current Output:

- 2 published papers in the Q1 international journals.
- 2 organizing workshops.
- 1 Master student, 1 PhD student, 3 Postdoctoral researchers.
- 5 theoretical knowledge in the form of manuscripts.
- 2 presentations in the international conferences.
- 2 prototypes in the form of mathematical programs and web applications.
- 20 research connections with experts within and outside Thailand.

Challenges/Problems and Possible solutions (if any):

The review process of the Q1 international journals can take a lot of time in which the submitted manuscripts might not be published within project duration.

Future plan:

- Continue to develop the theoretical knowledge.
- Continue to develop the research connections with other experts within and outside Thailand.

Development and Analysis of Optimality Conditions and Characterizations of the Optimal Solution Sets for Convex and Non-convex Optimization Problems

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Project duration: 3 year, from 1 November 2021 to 31 October 2024
Current progress: 80%

Abstract:

This project will investigate fundamental constraints for set-valued optimization problems using established structures or concepts for fundamental constraint derivation that serve as knowledge foundations. We will apply the researched optimal conditions to study the specific characteristics of the set of approximate minimum value points for convex optimization problems. We will explore the distinctive features of the set of approximate minimum value points for convex optimization problems in fractional programming formats and cone-constrained convex optimization problems. Additionally, we will devise the specific characteristics of the set of approximate minimum value points for robust convex optimization problems. In the final phase, we will develop possible solution radius that are robust for robust convex optimization problems in various formats. These will cover problems with linear programming constraints under the uncertainty of data. Furthermore, we will seek optimal conditions for reverse quasi-convex optimization problems, serving as sufficient conditions to confirm being minimum value points.

Rationales/Problem statements:

The problem of finding optimal values under constraints, known as constrained optimization problems, is a mathematical modeling approach that has garnered widespread interest and application in various fields such as economics, science, and engineering. These problems focus on finding maximum and minimum values of objective functions under certain constraint sets, using mathematical concepts and processes to guide the solution approach, making it an efficient and widely used model today. Therefore, studying the characteristics or patterns of constrained optimization problems is crucial and foundational for developing solution processes for increasingly complex problems. The example of applying different models for constrained optimization problems in real problem-solving scenarios includes: Convex optimization problems and robust convex optimization problems for supervised data classification, Non-Convex optimization problems for K-means clustering, Convex optimization and Non-Convex optimization for convolution neural network, Set valued optimization problems for Welfare Economics, Reverse quasi convex optimization problems for engineering design problem.

Objectives:

- Investigate the previously researched optimal conditions and explore the specific characteristics of the set of approximate minimum value points for convex optimization problems.
- Devise the specific features of the set of approximate minimum value points for convex optimization problems in fractional programming formats.
- Devise the specific characteristics of the set of approximate minimum value points for robust convex optimization problems.
- Develop the possible solution radius that are robust for robust convex optimization problems in various formats. These radii should cover problems with linear programming constraints under the uncertainty of data, such as robust semi-definite linear programming

problems.

Progress/Findings/Results:

On the 1st year

1. The researchers and the research team have established fundamental constraints for set-valued optimization problems using existing structures or concepts for deriving fundamental constraints, serving as foundational knowledge.
2. Study the specific characteristics of the solutions in Convex Semidefinite Programming using established structures or concepts for deriving fundamental constraints, serving as foundational knowledge
3. As a result, there are four publications in international journals.

On the 2nd year

1. Devise the specific characteristics of the set of approximate minimum value points for convex optimization problems in fractional programming formats and cone-constrained convex optimization problems. Additionally, introduce the regularized stochastic Nesterov's accelerated Quasi-Newton method to expedite the solution search efficiently. Furthermore, we have discovered the Smooth Support Vector Machine with generalized pinball loss for application in continuous classification of diverse types of data.
2. The two research findings have been submitted for publication which are
   - A Characterization for ε-Approximate Solution Sets of a Convex Semidefinite Programming (Revised)
   - Global optimality conditions for reverse quasi-convex programs (Submitted)

Conclusion:

In the research project, we have studied the specific characteristics of the set of minimum value points for various formulations of the problem of finding optimal values. We have identified the specific features of the set of approximate minimum value points for convex optimization problems in fractional programming and cone-constrained convex optimization formats. Additionally, we have developed the characteristics of the set of approximate minimum value points for convex optimization problems with robustness. Furthermore, we have discovered the Smooth Support Vector Machine with Generalized Pinball Loss for use in classifying diverse types of data. All activities align with the project's objectives, resulting in five research publications in the first and second years as follows:

- Published in the SJR Q1 database: 4 publications.
- Published in the SJR Q2 database: 1 publication.
- Submitted for publication in the SJR Q2 database: 2 publications.

Current Output:

On the 1st year

(1) An Improved Technique for Pneumonia Infected Patients Image Recognition Based on Combination Algorithm of Smooth Generalized Pinball SVM and Variational Autoencoders, *IEEE ACCESS*. 2022.3212535 (Scopus, Q1) Impact Factor 3.476

On the 2nd year

(1) Smooth support vector machine with generalized pinball loss for Pattern Classification, *Journal of Supercomputing*, 2023 (Scopus, Q2) Impact Factor 2.557

(2) Laplacian Twin Support Vector Machine With Pinball Loss for Semi-Supervised Classification, *IEEE Access*, 2023, 11, pp. 31399–31416 (Scopus, Q1) Impact Factor 3.476

(3) The regularized stochastic Nesterov's accelerated Quasi-Newton method with applications, *Journal of Computational and Applied Mathematics*, 2023, 428, 115190. (Scopus, Q1) Impact Factor 2.872

(4) A novel support vector machine with generalized pinball loss for uncertain data classification, Mathematical Methods in the Applied Sciences (Accepted) (Scopus, Q1) Impact Factor 3.171

Challenges/Problems and Possible solutions: -

Future plan:

- Study the determination of the possible robust solution radius for various formats of robust optimization problems to contribute to knowledge development.
- Develop possible robust solution radii for various formats of robust optimization problems that encompass linear programming constraints under data uncertainty.
- Find the optimal conditions for reverse quasi-convex optimization problems, which appear to be the inverse part of convex optimization, serving as sufficient conditions to confirm being minimum value points.

Phenomenological Dynamic Modeling of Patient Care and Management in COVID-19 Pandemic: Comorbidity and Age Related Factors

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 67%

Abstract:
Several investigations have been carried out after the unexpected discovery that coronavirus complication can appear a couple of weeks or sometimes months, after the initial COVID-19 infection. Increasing number of patients have been reported to develop life-threatening symptoms, such as patients developing worsening diabetes conditions, or experiencing higher loss of bone mass, especially in the elderlies. This necessitates immediate medical attention.

Rationales/Problem statements:
Although most patients will survive COVID infection, many experience long-term symptoms that frequently require medical attention. In order to better understand how to provide better patient care, we need the help of appropriate models.
Also, it has been reported that SARS-CoV-2 enhances the levels of angiotensin II by downregulating the expression of ACE2 and which then induces worsening inflammatory conditions. In addition, angiotensin II magnifies the differentiation of osteoclasts by boosting the expression of RANKL on osteoblasts and, as a result, enhances the development of osteoporosis in the rat model under observation.
Moreover, COVID-19 is reportedly transmitted through infectious airborne particles and droplets [8]. Infected persons release respiratory fluids carrying the SARS CoV-2 virus into the air when they breath, speak, cough, or sneeze. Particularly in indoor setting such as patients' rooms in hospitals, very fine droplets and particles easily spread through the air throughout the room or living space.

Objectives:
We construct and analyze models of glucose-insulin control system, incorporating the inflammatory responses in corona virus infection, and its treatment with certain drugs, which can impact the glucose-insulin control system in patients. Also, we investigate bone remodeling process when infection with SARS-Cov-2 is considered. The model is then analyzed so that we obtain delineating conditions for which different dynamics behavior can occur. In addition, we investigate how the weight of airborne infectious particles effects the dispersion patterns of corona virus in the patients' room in a hospital, by numerical simulations of a transport model for the incompressible laminar airflow.

Progress/Findings/Results:
We obtained conditions which ensure that the solutions remain bounded and local stability is maintained. In addition, the death rate of β-cells at zero glucose, must be small in comparison to the first order coefficient for β-cells replication. This means β-cells should be slow in dying and, at the same time, they should be able to replicate quickly even with low glucose activation. If such conditions are not met, the system should be recognized as defective. We discover, from the singular perturbation arguments, when symptoms of serious insulin resistance can be expected to develop, which reflects a disfunctional control system since it appears not to be able to produce insulin, or activate the β-cells to do so to decrease

the glucose level in the bloodstream. Insulin is not secreted sufficiently in response to high glucose and consequently, insulin level continues to drop necessitating exogenous insulin supplements to bring the system under control.

The model developed for bone remodeling process has been modified to incorporate the effects of Covid-19 on the reproductions of osteoblastic cells and osteoclastic cells. The resulting model is then analyzed theoretically using the geometric singular perturbation technique so that we obtain the conditions for which different dynamic behaviors can be expected. The results indicate that a periodic behaviour which has been observed clinically in the oscillations of the number of osteoclastic cells and osteoblastic cells, as well as the pulsatile secretions of PTH, [29], is permitted by our model. The number of osteoclasts in the presence of SARS-Cov-2 infection is higher than when SARS-Cov-2 infection is absent, whereas the number of osteoblasts with SARS-Cov-2 infection is lower and hence, more bone loss can be expected after Covid-19 infection.

The impact of the molar mass of airborne pathogens on the molar concentration of air and airborne pathogens at different locations in the patients' room has been investigated using Finite Element Technique to numerically solve the Initial Boundary Value Problem. The numerical results are obtained for a scenario in which the molar mass of airborne pathogens is 1 kg/mol and 5 kg/mol. The concentrations of both air and airborne pathogens are obtained at five different locations in the hospital room. We study the scenario in which the patients' room with dimension $10 \times 4 \times 2.5\ m^3$ is shared by four individuals. The room is equipped with a closed door, four air inlets on the ceiling, together with the mixture fluid flow inlet from the patients' nostrils, and four outlets on the wall above each patient's head, designed to release airborne pathogens from the room. We created the meshing of the computational domain, necessary for the finite element application.

Conclusion:

The question that needs to be answered is how we can care for patients with diseases that are concomitant to COVID-19, especially in the elderly, using the knowledge gained from creating and analyzing mathematical and computer models that empower us to predict the outcome of changes in conditions. As far as we know, there is no research using the creation and analysis of mathematical and computer models that can answer these questions deeply enough. Our research work shows that the use of carefully constructed mathematical models can play a crucial role in trying to provide personalized medical care, provided the results are properly analyzed and interpreted.

Current Output:

1. C. Rattanakul, Y. Lenbury, N. Khajohnsaksumeth, C. Modchang, Geometric Singular Perturbation Analysis of a Multiple Time-scale Model for Diabetes and COVID-19 Comorbidity, *WSEAS Transactions on Biology and Biomedicine*, DOI:10.37394/23208.2022.19.20.
2. C. Rattanakul and Y. Lenbury, Control of Blood Sugar in Diabetes and COVID-19 Comorbidity with Physical Exercise: Modelling by Impulsive System of Differential Equations, *WSEAS Transductions on Systems and Control*. DOI:10.37394/23203.2022.18.18.
3. C. Rattanakul, Bone Re modeling Process and Covid-19: A Modelling Approach. *WSEAS Transductions on Systems and Control*. DOI: 10.37394/23203.2022.18.32.
4. J. Suksamran, S. Amornsamarnkul, Y. Lenbury. Reaction-Diffusion-Integral System Modeling SARS-CoV-2 Infection-Induced versus Vaccine-Induced Immunity: Analytical Solutions and Stability Analysis, *IJAM*. Accepted after minor revision.
5. N. Khajohnsaksumeth, The Effect of Molar Weight on Airborne Infectiousness of Corona Virus, *WSEAS Transductions on Systems and Control*. Submitted.

Challenges/Problems and Possible solutions:

1. Budget limitation
2. Publication cost has sky rocketed.

Future plan:

1. Modeling the comparative outcome of vaccination versus pre-infections.
2. Investigation of other factors on the distribution patterns of SARS-CoV-2 is hospital rooms of various room designs, and different scenarios, to gain as much information as possible in order to find the optimum arrangements and designs for practical and safe utilization.

BRAINPOWER CONGRESS 2023
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ด้าน Global Partnerships (Medicinal & Virus)

Role of NS1 for Dengue Virus Replication and Pathogenicity and Ways to Counteract It

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[d]Functional Proteomics Technology Laboratory, Functional Ingredients and Food Innovation Research Group, National Center for Genetic Engineering and Biotechnology, National Science and Technology Development Agency, Thailand

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Project duration: 3 years, from 6 August 2022 to 15 August 2025

Current progress: 55%

Abstract:

Non-structural protein 1 (NS1) secreted from cells infected by dengue virus (DENV) is a major pathogenic factor contributing to dengue disease severity. Our clinical study indicated that the anti-parasitic drug ivermectin (IVM) lowers NS1 blood levels without affecting viremia. IVM targets nuclear transport by binding to importin-α, but how NS1 secretion in patients is suppressed by this drug is unknown. We show that IVM impairs folding and secretion of ER-luminal glycoproteins, including NS1. Proteomic analysis identified chaperones interacting with NS1, including GRp78 (78-kDa glucose-regulated protein). This chaperone is increased upon DENV infection via activation of the unfolded protein response (UPR). IVM blocked the nuclear transport of transcription factors required for UPR, thus impairing GRp78 upregulation and NS1 secretion. Reduction of GRp78 and NS1 secretion was also observed in IVM-treated patients. These results link nuclear transport and its inhibition by IVM to the folding and secretion of luminal glycoproteins, including NS1.

Rationales/Problem statements:

DENV is a major human pathogen causing around 100 million symptomatic infections annually. An important pathogenicity factor is NS1 which is required for viral replication and secreted from infected cells. Our clinical study indicated that the anti-parasitic drug, IVM could suppress NS1 blood levels, but the underlying mechanism remains elusive. One of the known mechanisms of IVM beyond affecting the chloride channels is the inhibition of nuclear import of proteins by binding to importin-α **(**IMPα**)** and inducing most likely a conformational change that prevents the interaction of IMPα with IMPβ1 to form the functional IMPα/β1 heterodimer. Interestingly, preliminary data from Dr. Bartenschlager's team have revealed that NS1 interacted with cytosolic IMPβ1 (or karyopherin β1/KPNβ1) and the knockdown of IMPβ1/KPNβ1 in hepatocytes significantly reduced NS1 secretion, partly by reducing intracellular NS1 amounts. However, the link between the IVM effect, IMPβ1, and NS1 production/secretion is not yet clear.

Objectives:
To characterize in-depth the role of IMPβ1/KPNβ1 and IVM in NS1 production/secretion, and additional host factors and pathways critically involved in DENV NS1 synthesis and release from cells. We propose the following aims: **1)** Study NS1 secretory pathway and the mechanism of how IMPβ1 contributes to NS1 stability and secretion; **2)** Decipher the mode of action of IVM and ways to increase its anti-NS1 potency using a repurposed drug strategy; **3)** Characterize additional host cell factors and pathways involved in NS1 production and secretion.; **4)** Correlate the *in vitro* data on NS1 secretion and involved host factor(s) with clinical data.

Progress/Findings/Results:
In the first year of our project, we aim to study the secretory pathway of NS1 and the mechanism of how IMPβ1/KPNβ1 contributes to NS1 stability and secretion as well as how IVM interferes with the NS1 secretory pathway. In a collaboration between Drs. Bartenschlager and Avirutnan's laboratories, we have used both genetic and biochemical approaches to decipher the mode of action of IVM. We have found that blockage of nuclear transport via IVM treatment or knockdown of the IVM-targeted protein KPNβ1 impairs secretion and folding of NS1 and other ER-luminal glycoproteins. Proteomic analysis identified chaperone proteins interacting with NS1 and likely assisting its folding. Among them was GRp78 which increased in abundance upon DENV infection via activation of the unfolded protein response (UPR). Nuclear transport blockage prevented the trafficking of transcription factors into the nucleus, impairing GRp78 up-regulation and thus, NS1 secretion. Upregulation of GRp78 and reduced NS1 secretion was also observed in patients treated with IVM. Altogether, these results highlight a general cellular pathway linking nuclear transport and its inhibition by IVM to the folding and secretion of luminal glycoproteins, including DENV NS1. Given that DENV NS1 is an important pathogenicity factor, the knowledge gained from this study would be useful for the future development of treatment of infected patients to lower severe dengue disease manifestations.

Conclusion: Our present study highlights that proper folding and secretion of DENV NS1(as a glycoprotein) requires nuclear transport of transcription factors induced via unfolded protein response (UPR). This pathway is targeted by IVM explaining the accelerated plasma clearance of NS1 in DENV-infected patients. We show that this effect is not limited to DENV NS1, but applies to a non-viral glycoprotein, thus highlighting a general cellular pathway linking nuclear transport with the folding and secretion of luminal glycoproteins.

Current Output:
A publication entitled "Dengue virus NS1 secretion is regulated via importin-subunit β1 controlling expression of the chaperone GRp78 and targeted by the clinical drug ivermectin" in *mBio* (https://doi.org/10.1128/mbio.01441-23)

Challenges/Problems and Possible solutions: none

Future plan:
In addition to IVM, we have identified two additional repurposed drugs with high anti-DENV efficacy [i.e., Ravidasvir (RAV) and Nelfinavir (NEL)] and found that the combination of these drugs could enhance anti-DENV activity as compared to the single drug use. We are in the process of characterizing the antiviral mechanisms of selected drug combinations against DENV infection and NS1 secretion.

Targeting Dengue Viral Nonstructural Protein 1 And Its Associated Host Cellular Proteins to Control Dengue Virus Infection and NS1-mediated Dengue Pathogenesis

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Project duration: 3 years, from 16 August 2022 to 15 August 2025

Current progress: 34%

Abstract: Dengue is one of the most important mosquito-borne viral diseases affecting almost half of the world's population. Infection with dengue virus (DENV) results in differential clinical manifestations in humans. The nonstructural protein 1 (NS1) of DENV is a key viral factor playing an important role in DENV production and dengue pathogenesis. Its plasma level also correlates with the severity of dengue. This study used computational, biochemical, and proteomic approaches to identify potential inhibitors targeting DENV NS1 protein and its associated host proteins and to investigate the mechanisms of intracellular signaling induced by the DENV NS1 protein that are responsible for virus replication, host inflammatory response and endothelial cell hyperpermeability (a pathogenic sign of vascular leakage). A set of small molecules binding to DENV NS1 protein was identified and tested for potential inhibition of endothelial barrier disruption and DENV infection. Their mechanisms of action were also further investigated by proteomic analysis.

Rationales/Problem statements:

Dengue causes a major public health problem globally due to increases in climate change, urbanization, travel, and transportation. DENV infection can lead to differential clinical outcomes in infected individuals with unclear underlying mechanisms. Licensed dengue vaccines have some limitations for use, and there is neither antiviral drug nor specific treatment for dengue. Plasma leakage is a hallmark of severe dengue and associated with circulating levels of DENV NS1 protein. NS1 is a multifunctional protein involved in DENV production, immune evasion, and induction of cytokine/chemokine production as well as transient endothelial barrier disruption which contribute to dengue pathogenesis. Thus, we hypothesize that DENV NS1 protein and its related host cellular proteins in response to DENV infection may serve as major targets for development of antiviral agents to control DENV infection and pathogenesis of dengue.

Objectives:

To investigate host phosphoprotein profiles involved in NS1 phosphorylation and NS1-induced endothelial barrier disruption using biochemical and proteomic approaches.

1. To search for new inhibitors specific against DENV NS1 protein, its host protein targets, and/or DENV NS1–host protein complexes, which might inhibit the function of DENV NS1 in virus replication and induction of dengue pathogenesis using computational methods.

2. To test inhibitory effects of inhibitors on DENV replication and NS1-induced endothelial barrier disruption and study their molecular mechanisms of action.

Progress/Findings/Results:

We have set up two vitro models of NS1-induced endothelial cell hyperpermeability to test functions of NS1 protein and its potential inhibitors and to investigate molecular mechanisms of endothelial barrier disruption. Wild-type NS1 and four NS1 phosphorylation mutants (T27A, T29A, T230A, and S233A) could induce endothelial cell hyperpermeability in both in vitro models, whereas Y32A mutation abrogated this NS1 function. In parallel, we have collaborated with a group of researchers at the University of Siegen (Germany) to perform computational analysis for virtual screening of FDA-approved drugs, kinase inhibitors, natural products, antimicrobial peptides, and metabolites available from public databases that can bind to DENV NS1 protein (dimeric structure). Ten small molecules were identified to interact with the dimeric NS1 protein. Three of them (i.e., curcumin, domperidone, and minocycline) were selected for further study based on their safety profile and available information related to DENV infection. Molecular dynamics (MD) simulations showed some common binding sites of these three small molecules in the β-roll region (Cys15 and Thr29) of DENV NS1 protein. Curcumin, domperidone, and minocycline, together with two NS1-binding peptides (peptide 3 and peptide 4), were found to significantly inhibit NS1-induced endothelial cell hyperpermeability. This inhibitory effect of minocycline could be observed even when treated at a concentration close to its plasma level previously reported after drug administration. In addition, domperidone could significantly reduce DENV RNA replication, viral protein expression, infectious virus production, and NS1 secretion in DENV-infected immortalized hepatocyte-like cell cultures. Moreover, we have set up an in vitro kinase assay to determine human kinases responsible for NS1 phosphorylation which might be involved in intracellular signal transduction leading to vascular leakage. Two out of five tested human serine/threonine kinases, i.e., NIMA-related kinase 2 (NEK2) and glycogen synthase kinase 3 (GSK3), were identified to be important factors for kinase activities of DENV NS1.

Conclusion:

1. The Y32 amino acid residue is essential for the ability of DENV NS1 to facilitate DENV production and induce endothelial cell hyperpermeability.
2. Curcumin, domperidone, and minocycline were identified as small molecules binding to the dimeric DENV NS1 protein and exerting the inhibitory effects on NS1-induced endothelial cell hyperpermeability.
3. Human NEK2 and GSK3 were important factors for kinase activities of DENV NS1.

Current Output:

Short-term training (2 months) of 2 B.Sc. students
2 poster presentations in national and international scientific meetings
1 manuscript (in preparation for Scientific Reports)
1 potential prototype for in vitro testing endothelial cell hyperpermeability (in preparation)

Challenges/Problems and Possible solutions: -

Future plan:

We will perform proteomic analysis to investigate host cellular protein profiles responsible for NS1-induced signal transduction leading to endothelial barrier disruption, and to explore the protective mechanisms of NS1-specific inhibitors. In addition, we will determine additional sets of potential inhibitors binding to (i) different forms of DENV NS1 protein (tetramer and hexamer), (ii) NS1-related host cellular proteins, and (iii) NS1-host protein complexes, and evaluate their potential inhibition of DENV infection and vascular leakage.

Molecular Mechanisms of Capsid Stabilization of Novel Podoviruses

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Project duration: 3 years, from 16/12/2021 to 15/12/2024
Current progress: 60 %

Abstract:
Bacterial virus or bacteriophage (phage) has emerged as an attractive antibacterial choice in agriculture, foods, and therapeutics. Phage offers three advantages: specificity to its host cell, self-replication ability, and non-toxic nature. However, low phage stability impedes phage utilization. Phage loses its infectivity when it experiences fluctuating external factors during storage and in-field application. This project aims to decipher stabilization mechanisms regulating the phage stability of the C22 and C19 phages. Both phages, discovered in Thailand, have been demonstrated for their biocontrol potential in eradicating pathogenic bacteria *Ralstonia solanacearum* (*Rs*), causing wilt disease in chili and tomato. Integrative biology, biochemistry, and nanotechnology approaches are employed to unveil stabilization mechanisms and phage stability. Information on the structure and dynamics will also open the possibility of engineering phages to improve their molecular properties. Our project will provide insight into structural dynamics and phage functions to overcome challenges in phage utilization for biocontrol.

Rationales/Problem statements:
C22 and C19 are non-enveloped phages with short tails and icosahedral capsids encapsulating genomic double-stranded DNA. While both phages exhibited promising results in lysing *Rs*, their low stability has been a challenge in storage and application. The phages drastically lose their infectivity. Our studies suggested structural alteration and interactions among capsid proteins regulate phage stability. The result urges us to explore the stabilization mechanisms of the C22 phage capsid, which govern the structure, dynamics, and stability of the C22 phage. The C19 phage is also studied. The C19 phage infects a different *Rs* strain than the C22 phage does. Knowledge of the stabilization mechanisms of C19 phage will allow us to optimize the combination of external factors that can prolong the stability of C19 phage. Combining C22 and C19 phages with the right external factors will lead to a phage cocktail for wilt disease with an expanding host range.

Objectives:
To determine the structures of C22 and/or C19 phage capsids in varying external factors using electron microscopy (EM)
To identify phage capsid protein subunits of the C22 and C19 phages in varying external factors using mass spectroscopy (MS)
To probe changes in nanomechanical properties and infectivity of C22 and C19 phages in varying external factors using atomic force microscopy (AFM) and infectivity assay
To achieve a joint proposal between BIOTEC, NSTDA (Thailand), and CSSB (Germany) for national or international funding

Progress/Findings/Results:

The work in this project is divided into five work packages (WPs 1-5). The WP1 is to achieve high-resolution structure images of C22 and C19 phage capsids. The WP2 is to verify the phage proteins. The WP3 is to investigate the phage nanomechanics and infectivity. The WP4 is the result dissemination, and the WP5 is the joint proposal. For WP1, Dr. Udom has received the training courses for sample quality control, vitrification, and screening and will continue data collection next year. For WP2, we determined and verified crucial phage proteins with genomic and proteomic data. For WP3, we understood the effect of external factors on phage stability and revealed the phage aggregation mechanism. For WP4, we published three publications and presented the work at two conferences. For WP5, we submitted two joint proposals on phage mechanisms and interaction with cell membranes. Although our project encountered a slow start at the beginning due to the COVID-19 situation, the project will be completed accordingly.

Conclusion:

We applied interdisciplinary approaches to understand the C22 and C19 phage stability. We employed genomic and proteomic methods to reveal the potential phage proteins and verified the phage proteins. The data are incorporated into the high-resolution phage structure. We also employed AFM to study the phage's nanomechanical properties. The data will be associated with infectivity. For the partnership and collaboration, Dr. Udom completed two visits to CSSB to initiate the structural study of C22 and C19 phages using electron microscopy. We organized joint meetings with Prof. Kolbe in Thailand and extended the collaboration on structural biology.

Current Output:

Sae-Ueng U, Bhunchoth A, Phironrit N, Treetong A, Sapcharoenkun C, Chatchawankanphanich O, Leartsakulpanich U, Chitnumsub P. "Thermoresponsive C22 phage stiffness modulates the phage infectivity." *Scientific Reports*, 12: 13001, 29/07/2022 [T1, IF = 4.996]

Manbua N, Suteewong T, Sae-Ueng U. "Efficacy of sugar excipients on lyophilized C22 phage infectivity evaluated by atomic force microscopy" *Biological Control*, 170, 104922, 07/2022 [Q1, IF = 3.687]

Sae-Ueng U. "Bacteriophages for wilt disease and sustainable agriculture" *International Conference of Young Scientists - Technological Innovations for Discovering Solutions to the World's Greatest Current Challenges*, 4-9 June 2023, Kigali, Rwanda [Oral presentation]

Bunsuwansakul C, Sae-Ueng U. "Aggregation of Novel Tailed Phage Observed by Atomic Force Microscopy (AFM)-Based Non-Contact Imaging" *The 40th MST International Conference*, 3-5 April 2023, Chonburi, Thailand [Poster presentation with the Best Poster Presentation Award]

Manbua N, Suteewong T, Sae-Ueng U. "Optimization of C22 Bacteriophage Lyophilization Factors Using Response Surface Methodology" *The 31st Thai Institute of Chemical Engineering and Applied Chemistry Conference*, 15-16 March 2022, Phitsanulok, Thailand [Proceeding]

Future plan:

The high-resolution structure images of the phage capsids will be collected in the next visit to CSSB. The data on the phage nanomechanical properties and infectivity will lead to a complete understanding of phage structures and dynamics. The work will serve as a partnership initiative in structural biology and biological physics for extended collaboration with CSSB, Germany, and other leading international institutes.

High-Resolution Virome Mapping and Surveillance of Arboviruses in Aedes Albopictus and Aedes Aegypti Vectors Across Life Cycle, Land Use and Spatiotemporal Patterns of Infection in Thailand

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Project duration: 3 years, from 16 August 2022 to 15 August 2025
Current progress: 40%

Abstracts:
Rapid environmental changes affect the biosphere at multiple scales and drive species adaptation. Infectious diseases have an impact on global health and our environment. Mosquitos have a prominent role as vectors of pathogens impacting human and animal health. The worldwide population at risk from mosquito-borne RNA viruses such as dengue, chikungunya, and zika virus has increased with the expansion of two key vectors, *Aedes aegypti*, and *Aedes albopictus*. These mosquito species have greatly expanded their distribution in the last five decades. Climate changes have been observed to impact mosquito vector populations in Thailand. Transovarial transmission (TOT) of arbovirus from infected female mosquitoes to eggs occurs in the natural cycles of these viruses and allows the vectors to act as reservoirs during interepidemic periods. High-throughput sequencing (HTS), has changed zoonosis surveillance, and vector genomics, giving unprecedented access to host-microbiota. In particular, HTS of total RNA has become the main method of RNA virus discovery. We need to address the most fundamental questions about their diversity, ecology, genomic structure, and impact on host and pathogen evolution. Moreover, the extensive surveys in this study revealed an astonishing number of strategies for genomic organization and adaptation on a larger scale than previously thought.

Rationales/Problem statements:
Arboviral diseases caused by DENV, ZIKV, CHIKV, JEV, and WNV have a high impact on the human and veterinary health of Thailand. DENV is hyperendemic, with some regions displaying long-term patterns of high dengue incidence (dengue hotspots). The major vectors *Ae. aegypti* and *Ae. albopictus* co-occur especially in urban areas and DENV. However, this mechanism of virus maintenance by TOT was suggested to have little influence on disease incidence, both in a general epidemiological context and relative to vector virome diversity. Mosquito populations will be studied, with emphasis on *Ae. albopictus* and Ae. aegypti, in two regions of Thailand with distinct historical patterns of dengue incidence: Ban Kha district, Ratchaburi province (DENV hotspot), and Saiyok district, Kanchanaburi province (DENV cold spot). The Ban Kha district has a population of about 25.000 inhabitants. The number of dengue cases recorded from 2016 to 2020 is 313, with a mean case number of 60.6/year. In the DENV cold spot region, the Saiyok district has approximately 62,000 inhabitants and a record of 65 dengue cases from 2016 to 2020.

Objectives:
Finding patterns of mosquito host selection is an essential aspect of understanding disease ecology and detection of unknown viruses with emergence potential:
1. How the vector community is structured concerning different land use types and how does it affect the circulation of important arboviruses?

2. How stable is the core virome of each vector across their developmental cycles and spatiotemporal distributions?
3. A metatranscriptomic framework for xenosurveillance and disentangling vector-virus-host networks:

Progress/Findings/Results:

In the hotspot region, rural areas exhibited the highest egg count, approximately twice that observed in both forested and urban regions. Across all three areas, outdoor egg production was almost double compared to indoor egg production. Coldspot regions showed similar patterns observed in hotspot regions; the rural area demonstrated the highest productivity, approximately twice that observed in both forested and urban regions. In all three regions, outdoor egg production exceeded indoor egg production by nearly twofold. The egg production of hotspots was two times higher than coldspots. A total of 750 ovitraps were set up in each area, resulting in 1500 ovitraps in total for both hotspots and coldspots. The trap positivity rate exhibited the highest prevalence in rural areas, while urban areas consistently showed the lowest rates among both hotspots and coldspots. Upon hatching the collected eggs to the sub-adult stages, the findings revealed that the urban environment exhibited the lowest emergence rate at 0.4%, representing a 15-fold reduction compared to rural areas (6%). Conversely, the forested area demonstrated the highest emergence rate at 11.6%, almost double that of rural areas. While the earlier observations indicated a higher prevalence in hotspot regions compared to coldspots, a contrasting outcome emerged in urban areas. While the survival rate remained consistent in hotspot regions, a substantial variation of approximately 30% was observed in coldspots. The average day of complete metamorphosis in coldspots was higher than in hotspots. The larva survey showed that clay dragon water jars, red clay water jars, small buckets, etc., are the most productive containers in both hotspots and coldspots. The most Aedes productive container was a plastic bucket, at 100%. Interestingly, no Aedes were found in big buckets. The most Culex productive container was big buckets, and conversely, no Culex was found in cement water tanks in either hotspots or coldspots. A similar pattern as ovitrap data, hotspots have double the number of coldspots. Aedes and Culex are the highest distribution across all areas. As per the previous data, these two species were more abundant in hotspot regions.

Conclusion:

The rural area is the primary location for egg production compared to forest and urban areas. The patterns of egg production through ovitraps and the prevalence of sub-adult stages identified in larva surveys exhibit similarities, with hotspots demonstrating a twofold increase over coldspots. Forest areas exhibit the highest egg-hatching rates, followed by rural areas, while urban areas display the lowest rates. Sub-adult survival remains stable in hotspots, but variations are evident in different coldspot areas. Mosquitoes in cold spots require more days to complete metamorphosis. In the larva survey, the most productive containers are consistent between hotspots and coldspots, predominantly featuring Clay dragon water jars, red clay water jars, and small buckets. Notably, large buckets are the sole container type devoid of Aedes spp. Conversely, for Culex, small cement tanks prove unproductive. Aedes and Culex emerge as the most abundant species across all areas, surpassing all other species by a factor of ten.

Current Output:

The patterns of egg production and the results of larval and mosquito surveys in hotspot and coldspot regions.

Challenges/Problems and Possible Solutions:
The captured mosquitoes are numerous, and the mosquito collection team needs time to categorize the mosquitoes and identify their species before sending them to the laboratory for virus testing. The laboratory will attempt to involve more scientists and students to assist in mosquito categorization, species identification, and virus detection in mosquitoes, aiming for more effective operational outcomes in the future.
Future plan:
Molecular detection of DENV, CHIKV, and ZIKV *in Ae. albopictus* and *Ae. aegypti* by using Realtime RT-PCR and sending the positive result for sequencing.

Dissecting the Role of Epitranscriptomic Regulation of Flavivirus RNA Genome in Interferon Activation

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Project duration: 3 year, from 16 August 2022 to 15 August 2025
Current progress: 30%

Abstract:
RNA modifications provide a versatile mechanism to modulate interactions between RNAs and other molecules to regulate a broad range of biological processes. Recent technological advances have linked RNA modifications to the regulation of coding RNAs, leading to the emergence of the new field of epitranscriptomics. While growing evidence indicates that the RNA genomes of flaviviruses and several other positive-strand RNA viruses harbor multiple forms of RNA modifications, little is known about their functions in the virus life cycle. Here, we propose to characterize the role of 2'-O-methylation on the RNA of dengue virus in immune antagonism in human cells and *Aedes aegypti* mosquito vector. We utilize our collection of mutant viruses to correlate the level of 2'-O-methylation and infection phenotypes. This exercise will provide a quantitative framework to understand the role of 2'-O-methylation in dengue virus infection and transmission.

Rationales/Problem statements:
Our group has identified a group of mutations in the methyltransferase (MTase) domain of dengue NS5 that could sensitize dengue virus toward type-I interferon at different levels. Structural mapping of the mutations indicate that these mutations could affect 2'-O-methylation levels on viral RNA. As this collection of mutations generated a gradient of viral interferon sensitivity, it offered a unique opportunity to investigate the regulation of activation of type I IFN response. To understand the effects of these MTase mutations, we propose a set of experiments to characterize its effect on 2'-O-methylation on viral RNA, on mosquito infection, and activation of interferon response. Integrative analyses of the data from these experiments could provide a quantitative novel insight into the activation of interferon response. This information could be useful for modulating immune response for developing live-attenuated dengue vaccine.

Objectives:
1. Characterization of RNA modifications on DENV genomic RNA of the MTase mutants
2. Characterization of the effect of DENV MTase mutants on mosquito infection and transmission
3. Characterization of the type I IFN induction by the DENV MTase mutants

Progress/Findings/Results:
We have defined three mutations that showed the same interferon sensitivity across different genetic backgrounds (DENV1 and ZIKV). We found that these mutants have different midgut and wholebody infection in *Aedes aegypti* mosquitoes. There is a strong correlation between the infection in the mosquito and the interferon sensitivity in mammalian cells, suggesting that there could be a conserved mechanism that both human interferon pathway and mosquito midgut used to restrict flavivirus infection. We also found that our MTase

DENV2 collection could be combined with STAT2 DENV2 mutants to produce another collection of mutant DENV2 that combined immune attenuation at different points of type-I IFN signaling, expanding the utility of our MTase mutant collections to modulate immune response. We have set up the protocol for RNA sequencing of DENV and are collecting data to analyze 2'-O-Me modification. This analysis capability will enable the next phase of analysis to profile 2'-O-Me of the MTase mutant DENVs to understand how viral RNA modification might modulate type-I IFN signaling. We have encountered a problem with generating DENV2-mCherry mutant virus stocks for single-cell analysis but a solution was found. In the next phase, we hope to obtain the data on the 2'-O-Me modification profile of the MTase mutants and to start the single-cell kinetic analysis of the MTase mutants.

Conclusion:

We identified a strong correlation between the infection in the mosquito and the interferon sensitivity, suggesting that there could be a conserved mechanism that both human interferon pathway and mosquito used to restrict flavivirus infection. We are currently performing a variety of analyses to understand the underlying mechanism.

Current Output:

1. DENV2 mutant collections attenuated via viral antagonistic functions against type-I interferon (prototype, patent in preparation).
2. Knock-out cells for improving dengue virus production (prototype, patent in preparation).

Challenges/Problems and Possible solutions: N/A

Future plan:

Characterization of MTase DENV2 and combined DENV2 mutants in human dendritic cells and macrophages (NVI grant), Analysis of infection kinetics by single-cell imaging of MTase DENV mutants, Analysis of immune response in *Aedes aegypti* using the DENV MTase mutants.

Development of Neutralizing Agents Targeting Glycopeptides Highly Conserved in SARS-CoV-2 Mutant Strains

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Project duration: 3 year, from 01 April 2023 to 31 March 2026

Current progress: 30%

Abstract:

Our joint project with NANOTEC (Thailand), AIST (Japan), and the Wistar Institute (USA) is developing neutralizing agents like monoclonal antibodies and aptamers to target SARS-CoV-2's stable glycopeptides. This reduces mutation effects. Using glycan technology, nanotechnology, and virology, we aim to improve these agents' precision and effectiveness. Our goal is to create new treatments and diagnostic tools for SARS-CoV-2 and establish methods that could help fight future infectious diseases, advancing antiviral research globally.

Rationales/Problem statements:

SARS-CoV-2 infection is initiated by its spike protein binding to host cells, with 22 N-glycans playing a key role, unchanged even in variants like Omicron. Our international team is developing antibodies and aptamers targeting these stable glycopeptides to neutralize the virus. These agents will be tested for blocking the virus from cell receptors and infection prevention. Additionally, we'll use advanced imaging to study the interaction of these agents with the spike protein. Our work aims to create therapeutics effective against existing and future variants, enhancing drug development and diagnostic capabilities.

Objectives:

The project aims to create antibodies and aptamers targeting SARS-CoV-2's stable glycopeptides, to combat current and future virus variants. It harnesses Japan's glycan technology techniques, the USA's virology knowledge, and Thailand's nanotechnology innovation for a treatment poised to enhance global health against COVID-19.

Progress/Findings/Results:

The progress report for our project over the past six months reflects significant advancements and collaborative efforts among the participating teams from Thailand, Japan, and the USA. At the project's inception, Dr. Deanpen Japrung and Ms. Wireeya Chawjiraphan of the Thailand team visited AIST, Japan, to strategize with our Japanese and American counterparts. This initial meeting focused on developing a framework for collaborative research, contract research, and student exchange programs. An integral part of this visit included a tour of Prof. Tateno's laboratory, where the Thailand team familiarized themselves with the facilities and interacted with potential exchange students. Since this foundational meeting, we have established a routine of online meetings to maintain regular

communication and synchronize our efforts across all research groups.

The Thailand research team has dedicated considerable effort to the selection of aptamers using the SELEX process, specifically targeting the commercial spike protein, a crucial element in SARS-CoV-2 infection. The plan is to conduct 5-6 rounds of this selection process, and we are currently in the midst of the second round. In parallel, our team has been employing aptamers identified in other groups' published works to perform computer simulation studies. These simulations are aimed at comprehending the binding mechanisms to the target protein. We are also exploring ways to modify these aptamers to improve their binding efficiency.

A significant milestone achieved by our team is the successful cloning and expression of spike and ACE2 proteins, pivotal in the SARS-CoV-2 infection mechanism. Utilizing this breakthrough, we have developed an advanced synthetic nanopore technology, complemented by AI analysis, for the detailed examination of spike and ACE2 encoded genes at the single-molecule level. This innovative approach has allowed us to observe distinct variations in both the quantity and structure of these genes. The development and application of this technology have not only enhanced our understanding of the virus's genetic makeup but also led to the drafting and filing of an intellectual property application. Our dedication to disseminating our findings has culminated in the submission of a manuscript to ACS Nano, detailing this significant advancement, which is currently under review.

In summary, our joint efforts have led to significant research progress in understanding SARS-CoV-2. Through teamwork, aptamer selection, and gene analysis, we've built a strong base for future discoveries. Our collaboration across countries is guiding us toward important scientific achievements.

Conclusion:

In the last six months, our international team has made great strides in SARS-CoV-2 research, with key meetings and significant advances in aptamer selection. We've cloned important proteins and innovated with AI-enhanced synthetic nanopore technology, leading to a potential patent and a manuscript under ACS Nano review. These steps underscore our dedication to fighting SARS-CoV-2 and pave the way for future scientific achievements.

Current Output:

1 intellectual property and 1 submitted manuscript in ACS NANO

Challenges/Problems and Possible solutions:

Our tri-national project encountered challenges with staggered starts and diverse contract laws causing delays. To resolve this, we'll synchronize timelines, facilitate consistent updates, and enlist legal advisors versed in international regulations. These actions will enhance collaboration and ensure adherence to our schedule.

Future plan:

Our focus will remain on selecting aptamers targeting SARS-CoV-2 proteins, analyzing their binding characteristics, and determining their complex structures. We'll also continue producing and purifying key glycosylated proteins for further study. To support this work, we'll align the international teams' schedules, consult legal experts for streamlined contract management, and conduct regular reviews, ensuring our research stays on course.

Optical-based Sensor for Virus Detection: Platform for Future Optical Sensing Applications

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Project duration: 3 years, from 16 December 2021 to 15 December 2024

Current progress: 70%

Abstract:

The "Optical-based Sensor for Virus Detection: Platform for Future Optical Sensing Applications" represents a comprehensive initiative directed towards the design, research, development, and testing of virus detection methodologies through optical sensors. The project places particular emphasis on two types of optical sensors, namely the guided-mode resonance (GMR) sensor and the plasmonic sensor. In addition to these advancements, a portable measurement device, characterized by handheld functionality and cost-effectiveness, has been developed for practical applications in the real world.

The principal objective of this undertaking is the reduction of both cost and time associated with virus detection, with the ultimate aim of application in point-of-care testing. Beyond immediate virus detection applications, the knowledge from this research serves as a foundational platform for prospective developments in diverse biochemical and biomolecular detection, including medical, food and agriculture, industries, and securities.

Rationales/Problem statements:

Since 2019, an outbreak of Coronavirus, specifically SARS-CoV-2, has been persisted to the present. In the initial phase, the absence of effective means for patient identification, medication, and vaccination protocol underscored the challenges. As a result, the outbreak rapidly and globally spread out, resulting in a cumulative count of over 690 million infections and more than 6.9 million deaths. Although the test-kit was introduced approximately a year later, the initial cost was excessively expensive at the beginning. Therefore, a novel platform for virus detection or other biomolecule detection is crucial study in order to prevent the potential future outbreak instantaneously. This research, hence, concentrates on the development of optical-based sensor for virus detection with the versatility to expend its applications to various biochemical detection applications.

Objectives:

1. To study and develop knowledge in the design, research, and development of optical sensor technology for virus detection. This will be an optical sensor platform for future applications.
2. To strengthen collaboration and exchange of knowledge with international researchers specializing in interdisciplinary fields, including knowledge in physics, optics, nanotechnology, biology, chemistry, virology, and medical sciences.

Progress/Findings/Results:

This research has been conducted for 2 years. Two types of optical-based sensors have been developed: guided-mode resonance (GMR) and plasmonic sensor. The design of both

sensors is facilitated through the utilization of simulation software. The fabrication process involved the application of nanoimprint and general complementary metal-oxide-semiconductor (C-MOS) techniques. A cumulative fabrication and characterization of over 100 sensors have been undertaken. For the purpose of biochemical substance detection, these sensors have been effectively surface-functionalized with many proteins, including general antigen/antibody pairs, protein A/G, and the spike protein of SARS-CoV-2.

In the course of sensing experiments, the GMR sensor demonstrated its capability to detect the SARS-CoV-2 pseudovirus in solid form. Furthermore, within the domain of liquid-phase detection, the GMR sensor was incorporated into an optofluidic system to facilitate Immunoglobulin IgG sensing, specifically in the binding process to protein A/G. The versatility of the GMR sensor extended to gas-phase detection, as indicated by its successful application in detecting and classifying Volatile Organic Compounds (VOCs). Concurrently, progress on another sensor, the plasmonic sensor, is nearing completion for functional testing within 3 months.

Conclusion:

The optical-based sensor for biochemical detection has been developed including simulation design, fabrication, and characterization. The guided-mode resonance (GMR) sensor is proved to detect solid, fluid, and gas phase of biochemicals which are the SARS-CoV-2 pseudovirus, protein IgG, Volatile Organic Compounds (VOCs), respectively. Concurrently, progress on another sensor, the plasmonic sensor, is nearing completion for functional testing.

Current Output:

3 publications

1. *Scientific Reports*, **13**, 1, 10799 (2023).
2. *Vacuum*, **214**, 112205 (2023).
3. *IEEE Sensors Journal*, **23**, 5 4700-4706 (2023).

2 publications in a reviewed process

1. *ACS Applied Nano Materials* (major review)
2. *Biosensors and Bioelectronics* (submitted).

Challenges/Problems and Possible solutions:

Future plan:

In the forthcoming year of research activity, the plasmonic-based sensor will be fabricated and tested, employing identical viruses and proteins for detection, thus facilitating a comprehensive comparison of sensor performance and effectiveness with guided-mode resonance (GMR). The conclusions drawn from this study will be summarized and published. All knowledges studied by this research will be shared with fellow Thai researchers and others through seminar and workshop. Moreover, this collaborative research partnership serves as the initial step to securing funding support for the advancement of commercial portable optical-based biochemical and biomolecule detection technologies.

Network of Programing Innate Immunity for Targeted Therapy in Cancer and Immune Related Diseases

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Project duration: 3 years, from 1 April 2022 to 1 April 2024
Current progress: 80%

Abstract:
The O6-methylguanine-DNA methyltransferase (MGMT) is a DNA suicide repair enzyme that might be important for macrophage survival after an induction. Then, mice with mgmt null (mgmt$^{flox/flox}$; LysM-Cre$^{cre/-}$) that do not have MGMT enzyme only in macrophages are created. With lipopolysaccharide (LPS) activation for M1 pro-inflammatory macrophage polarization, there is less severe inflammation in mgmt null macrophages than the control cells; supernatant cytokines (TNF-α, IL-6, and IL-10) and pro-inflammatory genes (iNOS and IL-1β), with higher DNA break (phosphohistone H2AX) and cell-free DNA. In tumor-associated macrophages (TAM; M2-liked condition), the mgmt null macrophages demonstrated more severe defect of mitochondrial activity (extracellular flux analysis). Hence, the loss of DNA repair causes more severe defect on mgmt null cells than control macrophages, perhaps through mitochondrial injury.

Rationales/Problem statements:
There was less severe sepsis (systemic responses against severe infection) and tumor burdens, the conditions controlled partly through M1-pro-inflammatory and M2-liked anti-inflammatory macrophage polarization, respectively, in mgmt null mice than control intact MGMT mice. The activation of both M1 (LPS) and M2 (supernatant of the cancer cell line) seems to induce stress on macrophages leading to cell injury and MGMT enzyme might partly be one of the mechanisms to restore macrophage function after the activation. With the lost of MGMT with DNA repair defect, both M1 and M2 macrophages have some defects. The defect of M1 in mgmt null mice causes less severe sepsis (loss of pro-inflammatory signals of M1 cells), while M2 defect cause higher abundance of tumor cells (loss of the support from TAM). Blockage of MGMT is interesting for both anti-inflammation and anti-cancer.

Objectives:
1. To explore the roles of MGMT in macrophage response in cancer and sepsis model using LysM-cre^{+-}; Mgmt $^{fl/fl}$ mice with proteomic and secretomic analysis
2. To explore the difference between wildtype mice (Mgmt $^{fl/fl}$) versus LysM-cre^{+-}; Mgmt $^{fl/fl}$ mice in subcutaneous cancer administration model
3. To explore the difference in sepsis hyper-inflammatory responses and sepsis immune suppression responses between wildtype mice (Mgmt $^{fl/fl}$) versus LysM-cre^{+-}; Mgmt $^{fl/fl}$ mice
4. To establish a platform of proteomic and secretomic analysis for transferring knowledge and its application to young Thai scientists.

Progress/Findings/Results:
The mgmt null mice show less severe sepsis than control mice (LPS injection and cecal ligation and puncture models). In parallel, lower tumor burden than control mice (subcutaneous injection of MC38 cell line of colon cancer). Perhaps, the enhanced DNA

breakdown from the loss of DNA repair by MGMT enzyme induced a stun effect in mgmt null macrophages leading to defects of both M1 and M2 macrophage polarization.

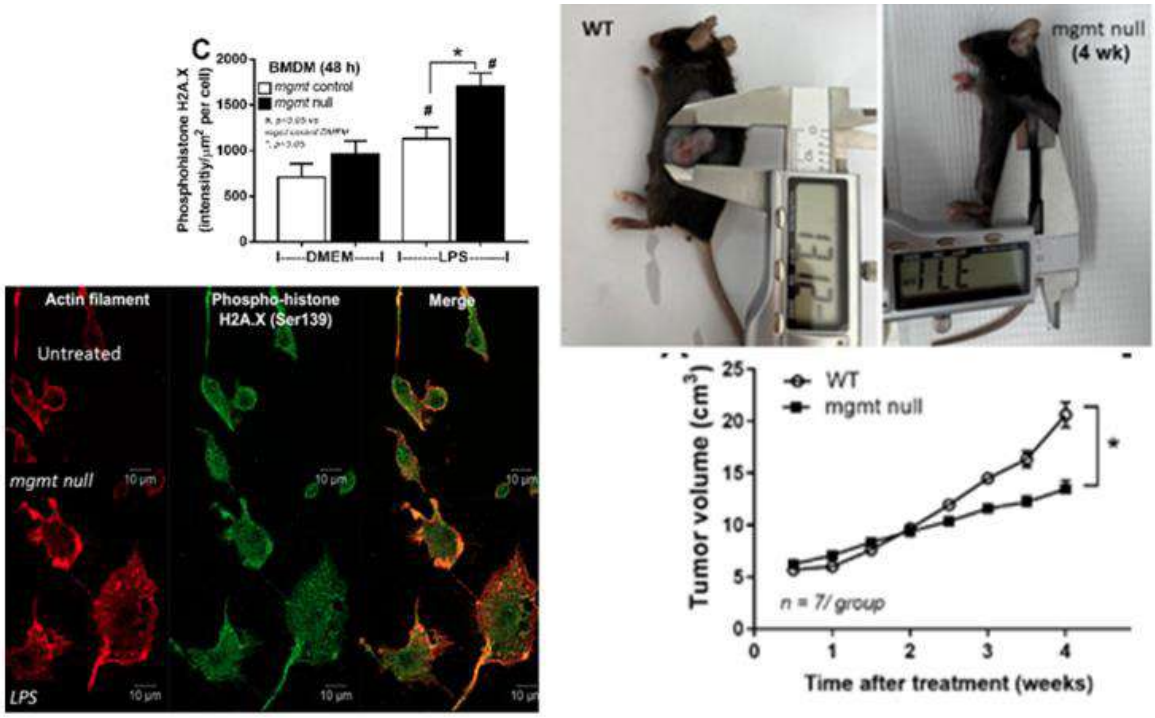

Figure 1 Cell injury might occur after stimulation in mgmt null macrophages) as indicated by DNA break (phosphohistone H2A.X) (left), and less abundance of tumor burdens (MC38 colon cancer) in mgmt. null mice compared with control (right).

Conclusion:

The new aspect of dengue infection, especially the correlation with the gut environment, will be explored. Here, we introduce LDGs and NETs as new biomarkers for dengue.

Current Output: 12 Published articles in Pubmed (higher than Q1 rank)

Challenges/Problems and Possible solutions:

The difficulty in breeding of the mice.

Future plan:

1. Exploring mgmt null mice in neutrophils aspect and other models.
2. Develop targeting treatment on macrophages for anti-inflammation in several conditions

Network of Programing Innate Immunity for Targeted Therapy in Cancer and Immune Related Diseases

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Project duration: 3 years, from 1 April 2022 to 1 April 2024
Current progress: 80%

Abstracts:

Despite a well-known association between gut barrier defect (leaky gut) and several diseases, data on the translocation of pathogen molecules, including bacterial DNA (blood bacteriome), lipopolysaccharide (LPS), and serum (1→3)-β-D-glucan (BG), from the gut to the blood circulation (gut translocation) in dengue is still less studied. Perhaps, dengue infection might induce gut translocation of several pathogenic molecules that enhance systemic inflammation affecting the disease severity. Currently, platelet count and liver enzyme (alanine transaminase) are the most important biomarkers of severe dengue. However, other parameters, including the indicators for leaky gut, systemic inflammation, and microbiome analysis, might have some roles. Hence, our current work with a collaboration from Australia, Japan, and Thailand will reveal more knowledge on this topic.

Rationales/Problem statements:

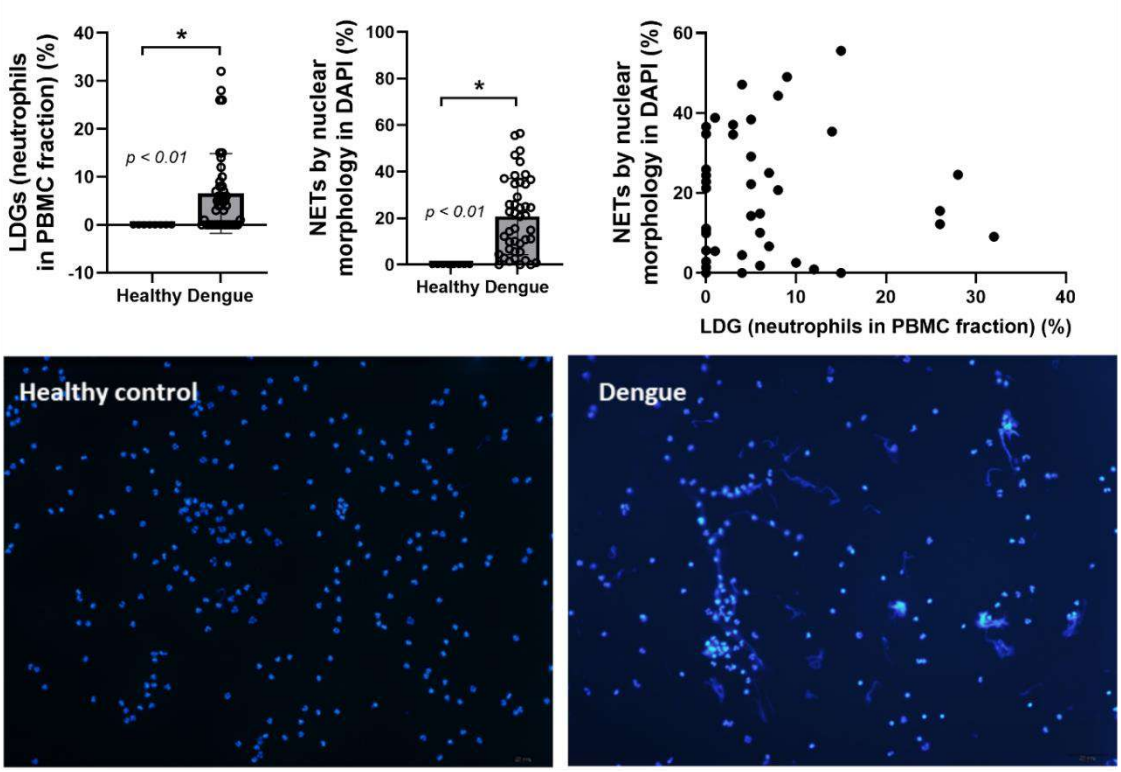
Despite the high prevalence of dengue infection, management of dengue is still the same as a decade ago. The expansion of resources available through this collaborative project will greatly boost our efforts to find new therapies. As there are possible close links between bacterial microbiome (feces and blood) and leaky gut with a limited investigation, we will investigate the fecal microbiome/ metabolome and blood microbiome in patients and examine the correlations with disease severity. With a combination among 3 countries, this project will enable us to determine changes within the gut bacteria, with implications for the causation of gut leak, and gain detailed information on metabolic features of the altered bacterial taxa. In our group, the Thai collaborators (clinical experience), the Australian team (Kate Stacey; 8 years' experience in dengue mouse models), and the Japanese group (Dieter Tourlousse; sequencing specialist) will ensure the investigation of this topic.

Objectives:

1. To investigate impacts of gut integrity on severity of patients with DENV infection
2. To evaluate the alteration of microbiome- and metabolome- associated with the increased severity of DENV infected patients
3. To establish a platform of microbiome and metabolome analysis for transferring knowledge and their application to young Thai scientists.

Progress/Findings/Results:

Low-density granulocytes (LDGs) and neutrophil extracellular traps (NETs) might be the new interesting parameter of disease severity, focusing on the systemic inflammation, of dengue. The sophisticate machine is not necessary to measure both parameters indicating a possible use in the real clinical practice. This enhanced systemic inflammation might be correlated with dengue-induced leaky gut.



รูปที่ 1 แสดงค่า low density granulocytes (LDGs) ด้วยวิธี gradient separation และ neutrophil extracellular traps (NETs) ด้วยการการย้อมโดยสี DAPI (ตัวอย่างผลย้อมแสดงในรูป) จากเลือดของอาสาสมัครสุภาพดี (10 ราย) และ Dengue (43 ราย) ไม่พบ LDGs และ NETs ในเลือดของอาสาสมัคร อย่างไรก็ดี LDGs ไม่มีความเกี่ยวข้องกับ NETs (r2 = 0.001)

Conclusion:

The new aspect of dengue infection, especially the correlation with the gut environment, will be explored. Here, we introduce LDGs and NETs as new biomarkers for dengue.

Current Output:

Challenges/Problems and Possible solutions:

1. The epidemiology of dengue is mostly in the rainy season in Thailand that might delay the patient recruitment.
2. Some of the patients do not pass stool during the course of infection which might limit the fecal sample of the project

Future plan:

Sample collection during the next season of dengue.

Network for Epigenetics of the Immune Cells in Health and Diseases

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 60%

Abstract:

The roles of epigenetics in immune cells are increasingly appreciated with the availability of the techniques to assess the epigenetic states of immune cells in different context and the inhibitors that target enzyme(s) that mediate the epigenetic reprograming. To elucidate epigenetic profiles by histone modifications of innate immune cells with limited cell numbers, we have acquired the cutting edges epigenetic techniques (CUT&RUN and CUT&Tag) to study epigenetic profiles of innate immune cells. The impact of mRNA vaccine on epigenetic changes of liver resident macrophages (F4/80+), including Kupffer cells (KC) in the liver were investigated. The transcriptomic profiles and an active histone mark, trimethylated lysine 4 on histone H3 (H3K4me3), was analyzed between mock and mRNA vaccinated mice. The impact of epigenetic regulation (Polycomb Repressive Complex enzyme, Ezh2) in innate immune cells in hepatocellular carcinomas (HCC) model was evaluated in myeloid-specific *Ezh2* KO mice.

Rationales/Problem statements:

Cells of the immune system rely on strict regulations to defend the host from external insults while remaining harmless to the host cells and tissues. Such regulations include acute signal transduction and cessation of the signals, transcription activators and repressors and modification of the epigenetic components. The roles of epigenetics in immune cells are increasingly appreciated with the availability of the techniques to assess the epigenetic states of immune cells in different context and the inhibitors that target enzyme(s) that mediate the epigenetic reprograming. Myeloid-specific deletion of epigenetic modifying enzyme in a mouse model is useful for evaluation of specific histone marks in the context of health and diseases.

Objectives:

1) To establish cutting edges epigenetic techniques for studying epigenetic profiles of innate immune cells

2) To study epigenetic profiles of innate immune cells after mRNA vaccination

3) To study epigenetic profiles of innate immune cells in disease model of cancers and immune-mediated diseases

4) To create a platform for transferring knowledge on epigenetics and its application to young Thai scientists

Progress/Findings/Results:

The roles of epigenetics in immune cells are increasingly appreciated with the availability of the techniques to assess the epigenetic states of immune cells in different context and the inhibitors that target enzyme(s) that mediate the epigenetic reprograming. To elucidate epigenetic profiles by histone modifications of innate immune cells with limited cell

numbers, we have acquired the cutting edges epigenetic profiling techniques (CUT&RUN and CUT&Tag) to study whole genome epigenetic patterns in the innate immune cells. In the first year, the impact of an mRNA vaccine on liver resident macrophages (F4/80+) was studied using model antigen mRNA delivered by lipid nanoparticles in mice. The transcriptomic analysis revealed an enriched interferon gamma and protein secretion hallmarks in mRNA vaccinated mice. An active histone mark profile, H3K4me3, was investigated in this subset of cells and significant increase in epigenetic profiles in clusters of gene loci were observed in mRNA vaccinated mice, indicating epigenetic marks by mRNA vaccination in liver resident macrophages. In the second year, the impact of epigenetic regulation in the innate immune cells in disease models, hepatocellular carcinomas (HCC) model in mice was established, using orthotopic intrasplenic transplantation of Dt81-Hepa1-6 cell line. The tumor formations were observed in livers and spleens as multinodular forms with no obvious metastasis, correlated with serum alpha-fetoprotein level. Ezh2 is a catalytic subunit of the polycomb repressive complex 2 (PRC2) that is responsible for deposition of trimethyl group on lysine 27 on histone H3 (H327me3). This histone mark on cis-regulatory regions is associated with gene silencing. Myeloid-specific *Ezh2* KO was used for interrogating the relevance of H327me3 on tumor-associated macrophages. First, an *in vitro* study using HCC cell line and *Ezh2* KO macrophages were performed. Co-culturing macrophages with Hepa1-6 cell line or culturing macrophages with the culture supernatant from Hepa1-6 cell line conditioned *Ezh2* KO macrophages to express markers of the wound-healing macrophage (M2). These markers include *Cd206*, *Arg1* and *Fizz1* which are often found in tumor-associated macrophages. The result indicated that lacking PRC2 and, as a result, the repressive histone mark in macrophages may promote tumor growth via pro-tumoral macrophages. The impact of *Ezh2* KO on HCC formation in vivo is under investigation. For an international networking, international collaborators were invited to give a joint symposium in Bangkok together with young Thai scientists on the topics of the innate immune cells in health and diseases. The topics included mechanistic insights into PRC functions, ceRNA and piwiRNA. Additional collaborators were added to the network from Mahasarakham University and Oita University (Japan).

Conclusion:

In this study, the impact of epigenetic modification in macrophages was investigated in immunization context and a tumor model using sensitive epigenomic method. Intramuscular administration of an mRNA vaccine affected liver resident macrophages, resulting in enriched interferon gamma hallmark. At epigenetic levels, significant increased active histone mark (H3K4me3) was observed in liver resident macrophages of mRNA vaccinated mice. Macrophages lacking *Ezh2* of the PRC2 adopted protumor phenotypes in the context of liver cancers, indicating that repressive histone mark, H3K27me3, plays essential roles in macrophages for promoting tumor growth.

Current Output:

1. 2 Publications in Q1 and Tier 1 journals
2. Two Ph.D. (Medical Microbiology, Biotechnology)

Challenges/Problems and Possible solutions:

In this study, mice with targeted gene deletion are used. The unpredictable nature of breeding made the experimental plan challenging. This may be the undesirable effect of gene deletion. More breeding pairs will be set up to circumvent this problem.

Future plan:

Myeloid-specific *Ezh2* KO mice will be used to evaluate the impact of H3K27me3 in macrophages in the context of cancer (liver cancer) and in autoimmune disease (lupus).

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
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ด้านงานวิจัยขั้นแนวหน้า (Global Partnership, Medicinal, Biotechnology, Future Food)

Development of Drug Delivery System for Inhibiting Cancer Aggressiveness via Targeting Tumor Microenvironment

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Project duration: 2.5 year, from 1/11/2021 to 30/4/2024

Current progress: 75%

Abstract:
Several types of nanoparticles (NPs) such as liposome and polymeric NPs have been designed to encapsulate and deliver active ingredients (polyphenol compounds, chemotherapy drug, and herbal extract) for antitumor activity in the treatment of colorectal cancer. The characterization of the nanoparticles by measuring particle size, examining morphology with TEM, assessing entrapment efficiency, and conducting a drug release study. The nanoparticles showed a spherical shape, ranging in size from 150 to 320 nm. The sustained release of the encapsulated compounds was observed in the formulated NPs. The cellular uptake of NPs was confirmed by flow cytometry analysis and fluorescence images. The effects of formulated liposome and polymeric NPs on cell cytotoxicity and apoptotic cells death against fibroblast, activated fibroblast and colorectal cancer cell line were determined. In addition, the synergistic effect of NPs combined with a chemotherapy drug was also studied.

Rationales/Problem statements:
Colorectal cancer (CRC) is a leading global cause of cancer-related deaths, with varying survival rates between developed and developing countries. Many studies have reported that liver metastasis is a significant contributor to CRC mortality, affecting a substantial percentage of patients. The tumor microenvironment (TME), comprising diverse cell types and extracellular components, plays a crucial role in tumor progression and drug resistance. The dense stromal nature of solid cancers, including CRC, poses a challenge for effective drug delivery. This study proposes a designed nanoparticle loaded multiple therapeutic agents to disrupt the crosstalk between cancer cells and the TME, particularly targeting cancer-associated fibroblasts (CAFs). Optimizing stability and bioavailability of nanomedicine is aimed at enhancing therapeutic efficiency in overcoming barriers to drug delivery, potentially offering a promising novel approach for anti-tumor activity in CRC treatment.

Objectives:
1. To develop a collaboration research between 3 institutions to create a high impact research
2. To develop targeted drug loaded nanoparticles for enhancing its stability and controllable release.
3. To investigate effect of formulated nanoparticles on cell proliferation, cell migration and invasion of cancer cells

Progress/Findings/Results:

This research focuses on the developing polymeric NPs to encapsulate resveratrol (RSV) and combine it with the chemotherapy drug or targeted treatment, Fluorouracil/Sunitinib (SUN), to inhibit the virulence of CRC. The effects of SUN and RSV on the viability of HT-29 cells were studied after 24 hours of treatment. Both SUN and RSV independently inhibited cell viability in a dose-dependent manner. Notably, the combination of RSV and SUN showed a synergistic effect, further enhancing the inhibition of HT-29 cell growth. Similar results were obtained using a 3D model of HT-29 cells.

To protect RSV from rapid metabolism and elimination from the bloodstream due to its short half-life (2-4 hours), RSV was encapsulated by polymeric NPs (P-RSV). These NPs were monodispersed with an average particle size of 178.4 ± 4.6 nm and a polydispersity index (PDI) of 0.081 ± 0.004. The *in vitro* RSV release behavior of P-RSV in PBS pH 7.4 is showed the sustained release pattern. Specifically, P-RSV released 31.4 ± 1.8%, 35.2 ± 0.3%, and 37.8 ± 1.4% of RSV at 24, 48, and 72 hours, respectively. The P-RSV effectively penetrated into HT-29 cells, exhibiting high fluorescence intensity with increasing NP concentration Cell viability decreased significantly with increasing P-RSV concentration, with a noticeable impact at 1 mg/mL. Both free RSV and P-RSV exhibited dose-dependent cytotoxicity in HT-29 cells at RSV concentrations of 16 to 128 µM compared to the control group. The combination of P-RSV and SUN showed the synergistic effect to decrease the viability of cells compared with using P-RSV or SUN alone in both 2D and 3D culture.

In addition, the encapsulation of resveratrol derivative, PHRE, into liposome (L-PHRE) was studied. These liposomes were approximately 188 nm in size and demonstrated good cellular uptake by HT-29 cells. L-PHRE was found to be effective in inducing apoptosis in HT-29 cells at a concentration of 50 µg/mL. A scratch assay revealed that L-PHRE significantly inhibited the movement of HT-29 cells compared to the control group. At concentrations of 25 and 50 ug/mL of PHRE, colon cancer cells moved significantly slower than the control group after 24 and 48 hours. This experiment suggests that lipid particles containing PHRE extract can effectively inhibit cancer cell invasion.

Conclusion:

This study explored the synergistic potential of combining resveratrol-loaded polymeric nanoparticles (P-RSV) with sunitinib (SUN) and a resveratrol derivative, PHRE, loaded in liposomes (L-PHRE) to inhibit HT-29 cell growth. Cytotoxicity assays revealed a synergistic effect between P-RSV and SUN, significantly suppressing HT-29 proliferation in both 2D and 3D cultures. L-PHRE, a novel nanoformulation, demonstrated its effectiveness in decreasing cell viability, inducing apoptosis, and inhibiting the invasion of HT-29 cells. These findings broaden the scope for future development and application of nanomedicine in improving colorectal cancer treatment.

Current Output:

- *Laboratory Prototypes*: 4 prototypes (polymeric and lipid nanoparticle containing polyphenol compounds and drug)
- *Publications*: 2 published paper (Tier 1, Quartile 1), 1 accepted paper (Quartile 1)
- *International conference*: 1 poster presentation at ESB2023

Challenges/Problems and Possible solutions:

Future plan:

International collaboration, involving visits to Kumamoto University and Glasgow University, aimed at advancing nanomedicine development and enhancing knowledge sharing and management practices in animal studies.

Elucidation of Molecular Targets and Mechanisms of Natural Products from *Mallotus spodocarpus* for the Development of Anticancer Therapeutics

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 50%

Abstract: Three novel cycloheptapeptides named mallotumides A−C with potent cytotoxicity (IC_{50} 0.60 to 4.02 nM) were isolated from the roots of *Mallotus spodocarpus*. The mechanism of action on CCA cells were explored and showed suppression of BrdU incorporation and cell cycle arrest at G0/G1 phases. At high concentration of mallotumide A, apoptosis was induced. The effects on cellular bioenergetic and metabolism indicated that mallotumide A could result in mild depletion of cellular ATP and reduction of expression of enzyme in fatty acid biosynthesis but not cholesterol biosynthesis. The enhancement in specificity to cancer cells could be achieved using encapsulation of mallotumide A in riboflavin functionalized PLGA nanoparticles. The *in silico* studies suggested the potential of mallotumide A as eukaryotic elongation factor-1α (eEF1A) inhibitors and designed derivatives for chemical syntheses. In addition, compounds isolated from *M. spodocarpus* also showed potential as anti-biofilm agents against pathogenic *Staphylococcus aureus* while not perturbing bacterial growth.

Rationales/Problem statements:

This research project has utilized the established research network between Mahidol University, National Health Research Institutes (Taiwan), and Academia Sinica (Taiwan) to foster the development of anticancer therapeutics based on natural compounds from *M. spodocarpus*. The extracts from *M. spodocarpus* previously showed highly cytotoxic activity. In order to develop natural products for therapeutics, we isolated pure compounds, elucidated complete structures, and constructed chemical modification for optimization. We evaluated cytotoxic activity against cancer cell lines *in vitro* and in mouse model *in vivo*. The detailed modes of action are explored using -omics and cellular biology. The delivery system is developed using nanotechnology. Artificial Intelligent (AI)-driven drug design is explored for obtaining systematic structural modification of lead compounds.

Objectives:

1. Investigation of chemical constituents in *M. spodocarpus* and their cytotoxic activity**.**
2. Investigation of mechanism of action including apoptosis, proliferation, cell cycle and cellular bioenergetic and metabolism as well as protein expression profiling in cancer cells of compounds from *M. spodocarpus* underlying potent anti-cancer activity.
3. Investigation of antibacterial activity of compounds isolated from *M. spodocarpus*.
4. Development of delivery system through compound encapsulation.
5. Investigation of binding modes of potent cytotoxic compounds from *M. spodocarpus* through *in silico* molecular docking.
6. To strengthen the established collaborations with research institutes (National Health Research Institutes and Academia Sinica) in Taiwan.

Progress/Findings/Results

Investigation of the chloroform extract of the roots of *M. spodocarpus* led to the isolation of three new cyclic heptapeptides named mallotumides A−C.

Mallotumides A−C exhibited a potent cytotoxic effect against six cancer cell lines (KKU-M213, FaDu, HT-29, MDA-MB-231, A549, and SH-SY5Y) as well as human cholangiocyte cells (MMNK-1) by the SRB assay. Mallotumide A was more potent than clinically used chemotherapy 5-FU at all time points and showed more sensitivity to cholangiocarcinoma (CCA) cells than MNNK-1 cells. To investigate mechanism of action, at 24 h, treatment of mallotumide A at a concentration of 0.01 μM significantly suppressed BrdU incorporation and arrested cell cycle at G0/G1 phases in both CCA cell lines. Moreover, apoptosis death was induced by mallotumide A only at the higher concentration. The

results indicated the cytostatic effect on CCA cells at lower concentrations and cytotoxic effect at higher concentrations. With regards to the cancer cell metabolism, mallotunide A caused reduction of ATP levels, accompanied by reduced energy sensing kinase (AMPK) in a dose-dependent manner both in colon (HCT116) and breast (MDA-MB-231) cell lines after 48 h treatment. Mallotunide A markedly down-regulated the expression of key enzymes in lipid metabolism including acetyl-CoA carboxylase-1 (ACC1), fatty acid synthase (FASN) and adipocyte-triglyceride lipase (ATGL) while it did not affect the expression of HMG-CoA reductase (HMGCR), a rate-limiting step enzyme of cholesterol biosynthesis.

Antibacterial activities were also explored. The susceptibility testings were performed at standard and significantly higher concentration. All compounds of isolated from *M. spodocarpus* could not affect growth of bacteria. The effects on biofilm formation in pathogenic *S. aureus* was determined and discovered that mallotumide A at 500 µg/mL could reduce biofilm formed to less than 10%.

The encapsulation of mallotumide A was studied. Mallotumide A encapsulated in riboflavin functionalized PLGA nanoparticles (PLGA-CSRf-(mallotumide A) was prepared and tested for its delivery efficiency to breast cancer cells (MDA-MB231, MCF-7). After treated cells for 48 h, PLGA-CSRf-(mallotumide A) nanoparticles decreased MDA-MB-231and MCF-7 cells with IC_{50} of 8.48 and 7.47 nM, respectively, as well as normal MCF-10A cell. However, higher than 50% of cell viability was observed with treated MCF-10A cells, suggesting the specificity of PLGA-CSRf-(mallotumide A) nanoparticles to target breast cancer cells with minor effects on normal cells. In addition, the mallotumide encapsulated nanoparticles also showed better inhibition of migration of MDA-MB231 cells.

A molecular docking analysis was performed on mallotumide A with eukaryotic elongation factor-1α (eEF1A). Mallotumide A showed a docking score similar to those of cyclic heptapeptides eEF1A inhibitors, ternatin and its derivatives, suggesting a strong binding affinity of mallotumide A to eEF1A. Among the designed mallotumide A-based analogues, at least 28 compounds exhibited similar or better docking scores than the parent mallotumide A, indicating their potential for further selection in chemical synthesis.

Conclusion:

Complete structural assignments of mallotumides A−C were accomplished. Mallotumides A−C showed remarkable cytotoxicity against cancer cells with inhibitory concentration in nM range. Mallotumide A showed more sensitivity to CCA cells with efficacy higher than 5-FU. The investigation of mechanism of action indicated that it could arrest cell cycle at G0/G1 phases in CCA cell lines. At low concentration, mallotumide A affected cytostatically on CCA cells. However, at higher concentration, apoptosis death was induced. The effects of mallotumide A on growth of colon and breast cancer cells were partly attributed to the mild depletion of cellular ATP and reduction of expression of enzyme in fatty acid biosynthesis but not cholesterol biosynthesis. The encapsulation of mallotumide A within the riboflavin functionalized PLGA nanoparticles could reduce the toxicity of mallotumide A in normal breast cells but still retain potent anticancer activity against breast cancer cells.

Current Output:

Publications (1 of 9)

1. Sawektreeratana, N.; Krachangchaeng, C.; Pittayanurak, P.; Betterley, N. M.; Chairoungdua, A.; Wongpan, A.; Panvongsa, W.; Janthakit, P.; Nalaoh, P.; Promarak, V.; Nuntasaen, N.; Reutrakul, V.; Kuhakarn, C.*; Hongthong, S.* "Mallotumides A−C: Potent Cytotoxic Cycloheptapeptides from the Roots of *Mallotus spodocarpus*" *Org. Lett.* doi.org/10.1021/acs.orglett.3c02641. (T1 article)

2.Three manuscripts are currently being prepared.

Academic meetings (1 of 2)

2023 THAILAND - TAIWAN BILATERAL SYMPOSIUM, July 23 - 26, 2023, Ayutthaya, Thailand.

Future plan: We currently carry out the syntheses of cycloheptapeptides using solid phase synthesis and the chemical modification of scopoletin isolated from *M. spodocarpus*. In addition to the *in vitro* cytotoxicity, the mouse model *in vivo* is planned. The main focus of future plan is to elucidate the molecular target underlying potent anti-cancer activity. The protein profiling of cancer cells treated with mallotumide A is undergoing. The metabolic effects on glycolysis and mitochondrial respiration in cancer cell lines will be investigated. With potential anti-biofilm activities of mallotumide A and natural analogues from *M. spodocarpus*, the efficacy of these compounds is being determined. The initiated discussion with Taiwanese collaborators resulted in the exploration of new encapsulation technique using a nanoliposome with mallotumide A. In addition, the knowledge transfer on AI-driven drug design platform is being discussed for designing novel compounds using mallotumide A as a template.

Development of mRNA Modified Immune Cell to Replace High Dose Chemotherapy in Bone Marrow Transplantation and Blood Cancer Treatment

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Project duration: 3 year, from 1 November 2021 to 31 October 2024
Current progress: 70%

Abstract:
This collaborative research between Chulalongkorn University and Shinshu University focuses on developing mRNA-based CAR T-cell therapy for chemotherapy-resistant acute myeloid leukemia (AML), targeting CD117 or c-Kit antigens. This transient expression system addresses patients who do not respond to standard chemotherapy or are intolerant to high-dose chemotherapy. The CAR transgene, featuring specific scFv, transmembrane, and intracellular signaling domains, is produced using in vitro transcription and electroporation for optimal efficiency. In vitro tests demonstrated the efficacy of mRNA CD117 CAR T cells in eliminating AML cells while sparing normal hematopoietic cells. In vivo studies employing two models aim to further investigate the therapeutic potential of these T cells. This research provides a promising avenue for advancing mRNA-based CAR T-cell therapy to replace high-dose chemotherapy as a bridging therapy for AML.

Rationales/Problem statements:
Acute myeloid leukemia (AML) is the most commonly diagnosed form of leukemia among Thai patients. The current standard treatment for AML involves risk-adjusted chemotherapeutic regimens. Despite continuous advancements in chemotherapeutic agents, the overall survival rate for AML patients remains at approximately 50%. Allogeneic hematopoietic stem cell transplantation (HSCT) becomes imperative for high-risk group or those with relapsed disease to enhance disease control and reduce relapse rates. However, only 20% of eligible patients are prepared for HSCT due to two significant challenges. First, disease control is often difficult to achieve before HSCT, as residual leukemia cells may impede the growth of donor hematopoietic stem cells. Second, some patients cannot tolerate the high-dose chemotherapy needed to eradicate cancer and normal hematopoietic cells before HSCT. To address these challenges, innovative treatments are essential, particularly for high-risk and relapsed AML patients requiring HSCT.

Objectives:
1. Development of mRNA-Based CAR T-Cell Therapy for the treatment of chemotherapy-resistant Acute Myeloid Leukemia (AML).
2. Efficacy evaluation of the developed mRNA-based CAR T-cell therapy both in vitro and in vivo.
3. Establishment of sustainable Collaborative Research with international experts to facilitate technology exchange, researcher development, and joint publications

Progress/Findings/Results:
The expression of CD117 across multiple AML cell lines and patient-derived primary AML blasts was investigated. CD117 was found to be expressed at high levels in leukemic cell

lines and at varying levels across patient samples. The nucleotide sequence of the CD117 CAR was designed, and its expression on primary T cells was tested using a retrovirus system. The sequence efficiently encoded CD117 CAR onto primary T cells, demonstrating specific targeting and effective elimination of CD117-positive AML cells in vitro. We then manufactured mRNA for expressing CD117 CAR with high quantity and purity. Preliminary testing shows that mRNA CD117 CAR can be efficiently delivered into primary T cells via electroporation, achieving a transfection efficiency of up to 90% with high cell viability. CD117 CAR T cells produced by mRNA electroporation exhibited rapid and highly efficient elimination of CD117-positive cancer cells. Additionally, unlike viral-based CAR T cells, the transient expression of mRNA-based CD117 CAR showed no toxicity toward hematopoietic stem cells. Moreover, we have developed mRNA-based CARs targeting other tumor antigens, such as CD19 and BCMA, using the developed protocol to expand the clinical use of mRNA gene editing technology.

Conclusion:

This collaborative research has successfully developed mRNA-based CAR T-cell therapy targeting CD117 for chemotherapy-resistant AML. mRNA-based CD117 CAR T cells exhibited efficient transfection and high efficacy in eliminating AML cells in vitro while sparing normal hematopoietic cells. Additionally, the developed protocol extends to other tumor antigens, suggesting the potential for broader clinical applications of mRNA gene editing technology.

Current Output:

1. Plasmid vectors and a robust in vitro transcription (IVT) process for mRNA production.
2. High-purity mRNA CD117 CAR, CD19 CAR, and BCMA CAR.
3. mRNA-based CD117 CAR T cells with CAR expression exceeding 90% demonstrated high efficacy in killing AML cells in vitro.
4. Optimal parameters for mRNA transfection in primary T cells using the electroporation technique.
5. One research article in a Q1 international journal.

Challenges/Problems and Possible solutions:

Generating humanized mice is difficult and costly. Collaboration with international partners is needed to set up this experiment.

Future plan:

Further in vivo experiments to evaluate the clinical potential of mRNA CD117 CAR T cells will be conducted by utilizing mice implanted with human hematopoietic stem cells to study the effects of mRNA-CD117 CAR T cells on normal hematopoietic cells and mice implanted with an AML cell line to investigate the frequency and dose of mRNA CAR T cells in AML elimination.

Generation of Pancreatic Beta-like Cells from Diabetic Patients-derived Induced Pluripotent Stem Cells (iPSCs) for Modelling of Mutation-Specific Pathogenesis

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Project duration: 2 years, from 1 November 2021 to 30 October 2023

Current progress: 50%

Abstract: Here, we study the pathogeneses caused by the mutations in the highly plausible candidate genes for familial form of diabetes, of which have been identified through whole exome sequencing. These include the mutations in genes encoding DNAJC3, RFX6, and INSL3. The studies have been conducted using different types of mouse and human continuous cell lines, primary mouse islet cells, and the beta-like cell derived from iPSCs of patients carrying the mutation. Our findings demonstrate the possible role of DNAJC3 in proinsulin folding and the response of beta-cells to ER stress, and the effect of the p.H238N on *DNAJC3* expression in response to ER-stress. The mutation p.P877fs disrupts translocation of RFX6, a transcription factor required for insulin production, to the nucleus. While the role of INSL3 relevant to maintenance of glucose homeostasis has not been established, our pilot study shows a correlation of plasma INSL3 level and insulin sensitivity index. The impairment of INSL3 secretion caused by the p.R4H mutation was also revealed. These findings affirm the diverse molecular processes underlying diabetes and pronounce the need of genetic dissection in diabetic patients, in order to allow the implement of precision medicine in diabetes.

Rationales/Problem statements: Despite many advances in the treatment, the morbidity and mortality associated with diabetes are still high. One of the reasons of the persistence of diabetes as a health problem is the limited impact of the current drugs on the natural history and broad spectrum of the disease. A better understanding of the molecular mechanisms underlying the development of diabetes is urgently needed, so that new and more effective therapeutics can be developed.

Objectives: To study pathology specific to the genetic basis of diabetic patients through an international research network by using different cellular models, including the patients-derived iPSCs.

Progress/Findings/Results: The mutations p.H238N, p.P877fs, and p.R4H, in a gene encoding DNAJC3, RFX6, and INSL3, respectively, showed the segregation with diabetes in the families studied and were considered as the highly plausible causes of diabetes. The studies in human beta-cell line endoC-BH1 as well as primary mouse islet cells demonstrated an increased expression of *DNAJC3*, a gene encoding co-chaperone of BiP, in ER-stress condition induced by thapsigagin. The induced expression of *DNAJC3* was also found in the islets isolated from Akita mice, a model of ER-stress related diabetes. Cycloheximide chase assay and WB analysis show that the p.H238N mutation attenuates ER stress-induced *DNAJC3* expression by destabilizing the synthesized protein. DNAJC3-depleted endoC-BH1 cells were generated by means of CRISPR-Cas9. However, the DNAJC3-knockout cells were unhealthy and could not be expanded, suggesting the role of DNAJC3 in beta-cell mass. Suppression of *DNAJC3* using shRNAs has been conducted instead. The knockdown cells showed a decrease in insulin secretion. The interaction between DNAJC3-BiP-proinsulin demonstrated through the co-IP experiments previously performed in human embryonic kidney HEK293 cells is being confirmed using gene rescue system on the background of DNAJC3-depleted HT1080 cells and DNAJC3-deficient endoC-BH1. The iPSCs derived from patients carrying the p.H238N mutation and a healthy non-carrier were generated and characterized for their pluripotency, differentiation capacity, and authentication. The mutation-corrected isogenic iPSCs were successfully constructed. CRISPR-Cas9 system was applied for generation of DNAJC3-depleted iPSCs. However, all the isolated clones showed only heterozygous genotype ($DNAJC3^{+/-}$). Although it is possible that the $iPSCs^{DNAJC3-/-}$ are not survived, our second attempt is ongoing by using the $iPSCs^{DNAJC3+/-}$ as a template. These iPSCs will be further differentiated into pancreatic beta-like cells for modeling of beta-cell dysfunction. Besides p.H238N-*DNAJC3*, a silent mutation (c.1419C>T, p.G473G) in *DNAJC3* was identified in a diabetic patient and predicted to activate cryptic splice site. Its effect on mRNA processing is under investigation using minigene assay. As revealed by immunofluorescence staining and confocal microscopy, the p.P877fs mutation in *RFX* disrupted nuclear translocation of the mutant protein. Gene overexpression system in HEK293 cells demonstrated the impairment of INSL3 secretion caused by the p.R4H mutation. INSL3 protein is mainly produced by reproductive cells. Mutations in *INSL3* have been reported as the causes of cryptorchidism. The role of INSL3 relevant to diabetes is not established. Interestingly, a pilot study in non-diabetic individuals demonstrated a correlation between plasma INSL3 level and Matsuda index (p=0.007), suggesting its role in insulin sensitivity. We identified INSL3 receptor (relaxin-like family peptide receptor 2; RXFP2) expressed in mouse insulinoma MIN6 cells and embryonic rat cardiomyocyte H9C2 cells. The role of INSL3 in insulin-stimulated GLUT4 translocation in H9C2 and the function of MIN6 cells will be determined.

Conclusion: Molecular mechanisms underlying diabetic pathogenesis are diverse.

Current Output: 2 manuscripts in preparation

Challenges/Problems and Possible solutions: While we want to split our data into small pieces, so that we can publish several works, our international collaborators want to gather all the data and publish it as only 1 paper. We, therefore, need to increase the number of our subprojects which consume more time and budget.

Future Plan: Transcriptomics of iPSC-derived beta-like cells will be generated and analyzed, to explore more novel molecules that can be considered as the targets for the development of more precise and effective drug.

Exploring Master Regulators of Immune Checkpoints (MR-IC) in Cancer

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 60%

Abstract:

Immune evasion is a key hallmark that propels cancer progression by modulating immune checkpoint molecule expression, immunosuppressive inflammation, and pro-tumoral immune cell infiltration. Current immunotherapeutic strategies have seen success by mitigating either one of these facets in 30-40% of patients, whilst others develop resistance or recurrence. Hence, the present investigation aims to identify a central therapeutic target to systemically impede immune evasion across cancers. Accordingly, a workflow was designed to identify and rank clinically relevant master regulators of immune checkpoints (MR-ICs) per cancer type. Preliminary evidence shows that therapeutic inhibition of the MR-IC in cholangiocarcinoma (CCA) cell lines results in transcriptional suppression of immune checkpoint marker, PD-L1, and immunosuppressive markers such as CX3CL1, IFNA21, IL4R in CCA cell lines. Our future work is directed towards functionally assessing if therapeutic inhibition of MR-IC potentiates immune mediated cell death in CCA cell lines and patient derived organoids.

Rationales/Problem statements:

Cancer is a multi-faceted disease propelled by various hallmarks including immune evasion. The hallmark of immune evasion enables tumors to evade immunosurveillance and elimination by modulating immune checkpoint molecule expression, immunosuppressive inflammation, and immune cell infiltration. Currently available immunotherapeutic options targets either one of these pillars of immune evasion through immune checkpoint blockade, cell-based therapies such as chimeric antigen receptor T-cells, and cytokine-based therapies.

While these treatment strategies have proven effective in clinical use for 30-40% of patients, there is a growing population of patients resistant to treatment of exhibiting recurrence. This compels the need for an alternative strategy that caters to the systemic inhibition of immune evasion across cancers.

Objectives:

Recognizing the caveats of current immunotherapy, our aim was to find a therapeutic target central to the three pillars of immune evasion (master regulators) for each cancer type. To achieve this aim, the following objectives were designed:

1. Develop a workflow that identifies candidate master regulators of co-inhibitory immune checkpoints (MR-IC) across all cancers.
2. Develop a scoring system to rank candidates based on clinical relevance, statistical significance, and enrichment scores.
3. Validate candidate master regulator (MR-IC) in vitro in its ability to transcriptionally regulate immune checkpoints.
4. Design a therapeutic strategy against the master regulator (MR-IC) and evaluate its potential to be clinically translational.

Progress/Findings/Results:

We applied therapeutic inhibition of MR-IC in CCA cell lines and evaluated changes in immune checkpoint protein expression using a proteome array. This result revealed that PD-L1 protein expression was reduced in both CCA cell lines. We were able to validate this finding using qPCR and western blot in KKU-M213 cell line but not in RBE. We hypothesize that RBE cell line may have compensatory mechanisms, and hence may not be an ideal candidate for further validation. Similarly, there seems to be contradictory expression levels of CTLA-4 between the proteome array and the qPCR and western blots. This may also be explained by compensatory mechanisms tumor-intrinsically as CTLA-4 is more typically expressed in T-cells as opposed to tumor cells. However, exploration of these compensation mechanisms lies beyond the scope of the present investigation. Additionally, inhibiting the MR-IC in CCA (by either small molecule inhibition or RNA interference) modulated the expression of various proteins involved in cytokine signaling and inflammatory pathways. This result is in line with our hypothesis as it depicts the relationship the MR may have in immune response processes in CCA. This result also shows us that therapeutic inhibition of the MR-IC in CCA, suppresses pro-tumoral inflammatory molecule expression such as CX3CL1, IFNA21, IL4R, and promotes anti-tumoral inflammation such as IL-18, IL-16, IL-11. Moreover, markers involved in immune evasive antigen presentation and processing were also found to be suppressed post treatment such as HLA-B, and anti-tumoral antigen presentation markers such as HLA-A, TAP1, and TAP2 were upregulated. This immunosuppressive reversal provides further confidence in pursuing this MR-IC in therapeutic translation. Cumulatively, these findings are particularly significant as it validates the relationship between the MR and IC, and provides further significance in assessing its translational potential in preclinical complex models. To clinically translate these findings in clinics, we assessed the effect of therapeutic inhibition of MR-IC on CCA cell viability. Moreover, we evaluated if the therapeutic inhibition of MR-IC synergizes with standard-of-care chemotherapy. Accordingly, our results revealed that MR-IC treatment was dose and time-dependently able to reduce the CCA cell viability. However, the IC50 of this drug ranges 40-45μM. While this concentration may seem relatively high to inhibit 50% cell viability, we further hypothesize that treatment of MR-IC potentiates immune mediated cell death. Therefore, the concentration required to induce immune cell activation and elimination of cancer cells may reduce. Additionally, we combined the MR-IC inhibitor with chemotherapeutics such as gemcitabine and cisplatin for CCA. Here, we found that the

combined treatment of CCA cell lines with MR-IC and chemotherapeutic agents: Cisplatin and Gemcitabine had marginal additive effects. While this result does not show promise in using MR-IC inhibition adjunct to standard-of-care, we maintain our hypothesis that treatment of the MR-IC should be evaluated in a co-culture system to evaluate the influence of MR-IC inhibition on the immune microenvironment. Our next steps, is to evaluate the immune mediated anti-tumor effects by inhibiting the MR-IC in a co-culture system.

Conclusion:

This investigation aims to offer an alternative immunotherapeutic strategy to combat the limitations of current immunotherapies. In this regard, MR-ICs were sought as ideal therapeutic targets to modulate immune checkpoint molecule expression, inflammation, and immune cell infiltration. Moreover, this investigation also offers a workflow to identify clinically relevant regulators that can be adapted to any other hallmark of cancer. We believe a systemic approach of identifying central drivers of cancer progression would be ideal for combating cancer progression.

Current Output:

Manuscripts in preparation:

- Review Paper: "Targeting MYC at the intersection of Cancer metabolism and oncoimmunology" submitted to Frontiers in Immunology.
- Original Article: "Immune Characterization of Thai triple negative breast cancer patients guides drug repositioning strategies" in preparation to be submitted to Frontiers in Immunology.

Posters Presented:

- "CCAImmune: An Immuno-oncogenic prognostic and therapeutic characterization of cholangiocarcinoma" - 82nd Annual Meeting of the Japanese Cancer Association 2023 (September 21-23, 2023)
- "Immune-Oncogenic characterization and molecularly guided drug repositioning for TNBC patients" – FAOBMB 2023 (November 22-25, 2023)

Oral Presentations:

- PRIMED symposium in Fred Hutchinson Cancer Center, Seattle, WA, USA (September 24-27, 2023)
- YBMB 2023, Nakhon Pathom, Thailand (November 19-21, 2023)

Challenges/Problems and Possible solutions:

Our findings are currently based on the success in one CCA cell line. We aim to expand the functional and mechanistic assays across multiple CCA cell lines to provide more confidence in the phenotypes observed. Moreover, our current method does not thoroughly address the sole effect of MR-IC depletion, and thus must be confirmed using CRISPR knockout assays. Lastly, to thoroughly assess the clinical potential of inhibiting MR-IC, a co-culture system must be used to visualize and evaluate the potentiation of immune mediated cell death *in vitro* and *ex vivo*.

Future plan:

In the coming months, we plan to assess the effect of MR-IC inhibition on immune-mediated cell death in CCA cell lines using CAR-T and effector T cell co-culture systems. Moreover, CCA cell lines will be surveyed to choose ideal candidates for further validation on gene and protein expression, and co-culture viability assays. Lastly, as a validation of our workflow in characterizing breast cancer in an immune context, we are preparing a manuscript for submission in Frontiers in Immunology.

Patient-Based *Stat3* L387R Gain-of-Function Variant Murine Model

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Project duration: 3 years, 1 November 2021 to 31 October 2024

Current progress: 50%

Abstract: Signal transducer and activator of transcription 3 *(STAT3)* is an important regulator found in a wide range of different immune cell types. Here we discovered a family with an inherited novel heterozygous *STAT3* p.L387R variant. Clinical phenotypes of these patients included recurrent infections, lymphoproliferation, and dermatitis. Distinct findings, such as pulmonary hypertension and ocular conditions, were also observed. In STAT3-transduced HEK293 cells carrying L387R variants, higher STAT3 phosphorylation and STAT3 downstream gene, *SOCS3*, were found. Moreover, T lymphocytes from these patients displayed increased expression of exhaustion markers. Mice with *STAT3* p.L387R variant were generated. None of the homozygous variant mice survive while heterozygous variant mice display dermatitis and splenomegaly. *Socs3* expressions from heterozygous mice spleen were significantly higher than that of WT mice. The extensive exploration of the effects upon this *STAT3* variant generated novel understandings of STAT3 in the human immune system.

Rationales/Problem statements: *STAT3* GOF variants can result in increased intrinsic STAT3 transcriptional activity or elevated expression of STAT3-target genes, including *SOCS3*. Although STAT3 hyperphosphorylation is usually not present in patients with *STAT3* GOF syndrome, reduced levels of pSTAT1 and/or pSTAT5 is frequently observed.

Several comprehensive reviews have recently summarized the diversity of genetic variants and disease phenotypes in *STAT3* GOF variants. These publications demonstrated the increasingly emerging disease manifestations along with the challenges in genotype-phenotype predictions. Thus, *STAT3* GOF variants still warrant functional investigation.

Indept studies into *STAT3* GOF variants is crucial for a comprehensive understanding. While explorations in human cell lines offer insights into the IL-6-STAT3 pathway, creating an animal model that mimics the human variant is imperative. Such a model can elucidate the physiological role of *STAT3* GOF in immune dysregulation and other organ dysfunction. Additionally, an animal model replicating the patient variant becomes instrumental in

exploring treatment options that hold promise for real patients.

Objectives: To characterize the clinical phenotype and molecular biology of the novel Stat3 L387R variant in a murine model, and to investigate appropriate therapeutic strategies.

Progress/Findings/Results: A family with two clinically affected individuals were enrolled in this study. The clinical disease spectrum of the patients was heterogeneous and overlapped that of previously published cases of STAT3 GOF variants. However, relatively rare findings, such as pulmonary hypertension and ocular conditions, were also observed in our cases. The variant results in an amino acid change at position 387 (p.[L387R])] and was predicted as "damaging" by SIFT. The described variant located in the DNA binding domain. The patient serum levels of the STAT3 regulated cytokines were markedly elevated. High Th17 lymphocytes and low Treg number was found in these patients. After IFN-α and IL-6 stimulation, pSTAT3 levels of transduced HEK293 cells carrying STAT3 L387R variants remained significantly higher than that of WT. Enhancement of STAT3 activity also measured in dual-luciferase reporter assay, SOCS3 mRNA expression, and DNA binding activity. Moreover, enhanced basal mitochondrial respiration was detected in the PBMCs of patients and their T lymphocytes also displayed increased expression of exhaustion markers. Homozygous *Stat3* L387R mice exhibited low delivery rates (4.2%), with 100% postnatal mortality. Heterozygous mice, comprising 30.2%, showed decreased weights post-weaning, while 25% developed dermatitis, with reduced sebaceous glands, hair follicles, collagen thickening, and chronic inflammation. Spleen and lymph node enlargement occurred in heterozygous *Stat3* L387R mice. Pathological examination of the heterozygous mouse spleens revealed extramedullary hematopoiesis. Upon IFN-α stimulation, phosphorylation of STAT3 in splenocytes peaked at 5–15 minutes, with a significant 15-minute increase in female heterozygous mice. Notably, Socs3 mRNA levels were also elevated in the spleen of heterozygous *Stat3* L387R mice. Interestingly, some *Stat3* L387R mice showed eye abnormalites as well. However, no distinct pathology was observed in the eye lesion. To explore molecular mechanism, we also introduced *Stat3* GOF mutation into the retinal pigmented epithelial cells. The cells with *Stat3* GOF mutation including L387R showed upregulation of phosphorylated STAT3 and SOCS3 as expected. The transcriptomic analysis showed distinct profile.

Conclusion: We discovered a heterozygous *STAT3* variant in a family with immune dysregulation and diverse comorbidities. The patients express diverse clinical phenotypes in addition to previously reported patients with *STAT3* GOF variants. Extensive biological studies confirmed GOF phenotypes in phosphorylation, nuclear migration, and DNA binding. Our murine Stat3 L387R model was created and even in a specific pathogen-free environment, the model revealed distinguished pathological phenotypes similar to the patients. Developing patient-specific transgenic *Stat3* GOF mouse models could enhance our understanding of disease pathophysiology, paving the way for individualized therapies for those with *STAT3* GOF variants.

Current Output: One review article and two original research articles are anticipated for submission in the near future.

Challenges/Problems and Possible solutions:

- Limited availability of personnel that may impede research progress
- Costly chemicals and animal care
- Time constraint

Future plan:

- Gene editing and transplantation
- Challenge infection in mice to see different phenotypes

Mechanical Force and the Control of Oral Stem Cell Behaviour

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Project duration: 3 years, from 1 November 2021 to 31October 2024

Current progress: 88.88 %

Abstract:

Dental and oral structure are subjected to various force types during normal functions. Mechanical stimuli play the critical roles in both physiological homeostasis and pathological progression. Our group elucidated the role of different force types in regulation of oral stem cell responses and the involved cellular mechanisms. Different force types led to the distinct potency in stimulation of cell responses. Intermittent but not continuous compressive promoted osteogenic differentiation in human periodontal ligament stem cells and murine induced pluripotent stem cells, possibly via TGF-β pathway. Force stimulation also led to the release of adenosine triphosphate (ATP). These released ATP further functioned in regulation of immunomodulation and inflammation in human periodontal ligament cells, which subsequently regulated T cell proliferation and Treg differentiation. In conclusion, the present study reveals the distinct role of specific mechanical stimulation on cell responses.

Rationales/Problem statements:

Mechanical forces stimulate cell responses leading to the control and regulation of tissue homeostasis and functions. In the oral cavity, there are numerous oral tissues that are subjected to mechanical force during normal functions. Among several oral structures, the periodontal ligament is one of the main tissues regularly receiving mechanical force. The main function of the periodontal ligament is to withstand the mechanical forces generated from the function of the oral cavity including mastication, deglutition, and speech. Low or high forces applied to periodontal tissue leads to atrophy and destruction of alveolar bone and periodontal ligament, subsequently causing diseases. Various factors must be considered to understand the role of mechanical stimulation in the regulation of specific biological functions, including force type, duration, and magnitude. Hence, understanding the specific biological processes of force-modulated cell response could be further used to utilize mechanical force to guide cells toward the desired function.

Objectives:

1. To examine the signalling regulation of mechanical force-induced osteogenic differentiation of oral stem cells.
2. To investigate the influence of mechanical force-regulated immunomodulatory effects on oral stem cells.
3. To investigate the role of the extracellular matrix and its receptors in cell responses under mechanical force stimuli.

Results:
The crucial role of mechanical force in maintaining periodontal tissue homeostasis was examined using rat molar hypofunction model. Teeth that not subjected to occlusal force exhibited the decreased periodontal space, the disorientation of periodontal ligament fibers, and the altered extracellular matrix component of periodontal ligaments. In the *in* vtiro study, Intermittent compressive force differentially controlled gene expression as determined by a high throughput RNA sequencing. The upregulated genes were related to extracellular matrix (ECM)-receptor interaction, focal adhesion, and transforming growth factor β signaling pathway, while the downregulated genes were involved in calcium signaling pathway. Intermittent compressive force promoted osteogenic differentiation in both human periodontal ligament stem cells and murine induced pluripotent stem cells via transforming growth factor β pathway. Further, intermittent compressive force increased the release of adenosine triphosphate. Extracellular adenosine triphosphate bound to P2 receptor families and subsequently regulated several functions of human periodontal ligament cells. Different concentration of adenosine triphosphate differentially control inflammation. Low concentration promoted pro-inflammatory responses while high concentration enhanced anti-inflammatory effects of human periodontal ligament cells. Further, adenosine triphosphate modulated the immunosuppression properties. It was also shown that shear force modulated immunosuppressive properties of human periodontal ligament cells via ERK pathway, which further suppressed T cell proliferation and promoted Treg differentiation.

Conclusion:
Taking all evidence together, mechanical force promotes distinctive biological responses depending on force types and cell types. Pretreatment with intermittent compressive force promoted osteogenic differentiation in multipotent and pluripotent stem cells of oral cavity. Beside, mechanical stimulations led to the change of immunomodulatory properties of dental stem cells. These regulations are occurred through different intracellular signaling. The information implicates the utilization of mechanical force in the modulation of oral cell responses toward specific utilization.

Current Output:
8 Publications in T1/Q1 journal, 10 new researchers, 4 international networks

1. Na Nan D, et al. Oral Dis 2023 Jul 19. Doi:10.1111/odi.14691.
2. Na Nan D, et al. BDJ Open 2023; 9(1):31.
3. Kyawsoewin M, et al. BDJ Open 2023; 9(1):28.
4. Limjeerajarus N, Heliyon 2023; 9(3):e14276.
5. Chanseanroj A, et al. Int J Mol Sci 2022; 23(22):13897.
6. Suwittayarak R, et al. Int J Mol Sci 2022; 23: 7119.
7. Manokawinchoke J, et al. J Dent Sci 2023;18(1):105-111.
8. Limraksasin P, et al. Sci Rep 2022;12(1):19021.

Challenges/Problems and Possible solutions:
The research budget transfer and allocation were delayed more than 5 months in all installment period. The project managers solved this critical challenge by advancing personal budget in order to run project smoothly.

Future plan: The study of mechanobiology field is limited in Thailand. Collaborative network of local researchers and linking to international investigators are indeed necessitate to foster young investigator and build-up the strong fundamental study in this field. The *in vivo* study should be further examined in order to understand the complex regulation of force on biological responses. In addition, the multi-omics approaches should be implemented to further understand and dissect the cellular and molecular regulatory mechanism.

Increasing Pluripotency of Stem Cells by the Conversion of Primed to Naive State of Rhesus Monkey Embryonic Stem Cells

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Project duration: 3 years, from 31 November 2021 to 30 October 2024

Current progress: 65%

Abstracts: In experiment 1, FPA-FTIR microspectroscopy technique detected biomolecules of both primed and naïve rhESCs showed the potential of FPA-FTIR microspectroscopy that can be distinguished both types of cells. The data from Principal Component Analysis (PCA) analysis confirmed that FPA-FTIR microspectroscopy technique can be highly separated primed and naïve rhESCs.

In experiment 2, the converting primed to naïve state Gorilla, Orangutan and Bonobo iPSCs showed that Gorilla and Orangutan iPSCs could maintain on laminin coated dish whereas Bonobo iPSCs could not. Bonobo iPSCs could grow on feeder cells. When cultured three cell lines on feeder cells in VALGöX medium for 9-12 days showed that they expressed pluripotent markers (Nanog and Oct-4) similar to primed state cells. After switched culture in ALGöX medium for another 12-15 days, all three cell lines still expressed pluripotent markers, however, did not express KLF17 and TFAP2C which are specific markers of naïve state and did not show dome-like shape colony. Culturing all three cell lines on feeder cells in VALGöX+CB showed more clearer edge, expressed pluripotent markers, however, did not express KLF17 and TFAP2C which are specific markers of naïve state.

Rationales/Problem statements:

In rodents, PSC-based systemic chimeras in association with gene disruption technology have been instrumental in elucidating developmental pathways and cellular functions of healthy and diseased animals. This has paved the way to the generation of animal models of human genetic disorders. However, increasing evidence indicates that the developmental mechanisms and gene expression programs described in rodents are not fully conserved during evolution and that significant differences exist when compared with their primate counterparts. Because of these reasons, it is now generally accepted that the development of reverse genetics in non-human primates is an important goal in developmental biology as well as for the generation of primate models of human genetic disorders.

Objectives:

1. To Characterization of rhesus monkey embryonic stem cells (rhESCs) between primed stage VS naïve stage using Focal-Plane Array (FPA) IR imaging.
2. To Converting prime to naïve states of Gorilla, Orangutan and Bonobo iPSCs in VALGöX/ALGöX medium.

Progress/Findings/Results:

Experiment 1: The results of using FPA-FTIR microspectroscopy technique for detecting biomolecules of both primed and naïve rhESCs showed the potential of FPA-FTIR microspectroscopy that can be distinguished both types of cells. This technique based on

the separation infrared spectra of three biomolecules including lipid, protein and nucleic acid. For lipid (region 2950, 2920, 2870 and 2850 cm^{-1}), ketone group (region1760 cm^{-1}), protein (region 1700-1600 cm^{-1}) which separated in two groups included Amide I (region 1635 cm^{-1}), Amide II (region 1550 cm^{-1}) and nucleic acid (region 1200-900 cm^{-1}). The data from Principal Component Analysis (PCA) analysis confirmed that FPA-FTIR microspectroscopy technique can be separated primed and naïve rhESCs.

Experiment 2: The results of converting primed to naïve states of Gorilla, Orangutan and Bonobo iPSCs showed that Gorilla and Orangutan iPSCs could maintain on laminin coated dish whereas Bonobo iPSCs could not survive on laminin coated dish beyond passage 6. Then, we changed the culture system of Bonobo iPSCs on feeder cells (mouse embryonic fibroblasts, OF1) which improved cell survival. At the first step of culture in VALGöX medium for 9-12 days found that all three cell lines expressed pluripotent markers (Nanog and Oct-4) similar as primed state cells. At the second step of culture in ALGöX medium for another 12-15 days found that all three cell lines still expressed pluripotent markers, however, did not express KLF17 and TFAP2C which are specific markers of naïve state and did not show dome-like shape colony. We further investigated by culture all three cell lines on feeder cells in VALGöX+CB. The morphology of three cell line showed more clearer edge, expressed pluripotent markers, however, did not express KLF17 and TFAP2C which are specific markers of naïve state.

We also investigated the colonization capacity by cultured three cell lines on feeder cells in VALGöX/ALGöX and injected 8-10 cells into each morula stage rabbit embryos and cultured embryos for 2 days. The results showed that all three cell lines could not colonize with the host embryos.

Conclusion:

The first experiment demonstrated that FPA IR imaging showed unique fingerprints of biomolecules that were highly separated primed and naïve states rhESCs.

The second experiment can be concluded that we could not converting primed to naïve state of Gorilla, Orangutan and Bonobo iPSCs. Next step of research needs to find out other signal which associate with maintaining pluripotency and support naïve state in all steps of culture period.

Current Output:

1. Published paper: Anwised, P. et al. (2023). Stem Cell Reports. 18: 1-22.
2. Manuscript in progress: Resetting naïve state features with epigenetic inhibitors in rabbit iPS cells (For Stem Cell Research)
3. Manuscript in progress: hStat3-ERT2 overexpression failed to maintain naïve pluripotency during rabbit embryonic stem cell derivation (For Stem Cell Reports)
4. Manuscript in progress: Characterization of NHPs iPSCs differentiation between primed stage vs naïve state using Focal-Plane Array (FPA) IR imaging (For Stem Cell Research and Therapy)
5. Manuscript in progress: Colonization of naïve Chimpanzee iPSCs into host embryos (For Nature Cell Biology)

Challenges/Problems and Possible solutions: None

Future plan:

1. Examine neural differentiation capacity of primed and naïve states rhESCs.
2. Converting primed to naïve states rhESCs using conditioned medium from human mesenchymal stem cells to establish xeno-free culture system.
3. Converting prime to naïve state of Gorilla, Orangutan and Bonobo iPSCs using small molecules supplementation.

***In vitro* Cattle Stem Cell Cultivation to Serve the Generation of a Future Food; Cultured Meat**

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Project duration: 1 year, from 1 August 2022 to 31 July 2023 (with 6 moth extension to 31 January 2024)

Current progress: 55%

Abstract: Increasing requirements food supply is gradually increasing with the estimation of a 76% increase in meat requirement in 2050 estimated by the Food and Agriculture Organization (FAO), The United Nations. The improvement of meat production from livestock and aquatic farms impacts animal welfare, the environment, and human health. Replacing the meat with cell-based meat might be helpful. The present project aims to generate immortalized muscle stem cells (satellite cells) and fibro-adipogenic stem cells (FAP) from local good meat-producing cattle from Sakon Nakhon province, Pon Yang Kham cattle. Meat was obtained from GMO-grade Livestock Breeding, processed, and transported to Khon Kaen University for cell isolation and culture. Satellite cells and FAP were isolated by fluorescence-activated cell sorting (FACS). The newly designed plasmid immortalized cells are generated and characterized, confirming the ability to create muscle and adipocyte cells. Ultimately, the project's outcome might help develop cell-based meat in the future.

Rationales/Problem statements: The meat was obtained from the left-over part and transported in the specified condition for long-distance transportation. Cells were isolated from beef and were sorted by FACS. Satellite cells and FAP were isolated and characterized. Some were immortalized by the newly designed plasmid. The characteristics of primary and immortalized cells were compared to ensure comparable properties.

Objectives:

1) To establish the satellite cells and FAP from Pon Yang Kham cattle and characterize the properties of cells
2) To generate the immortalized satellite cells and FAP from the newly designed plasmid
3) To compare the cell characteristics between primary isolated stem cells and immortalized stem cells

Progress/Findings/Results: Tissue transportation, cell isolation, and primary cell culture protocol were established. Primary cells were characterized. Stem cell populations were sorted and immortalized. The characteristics of primary stem cells and immortalized stem cells are compared. However, the processes require more extended time than expected due to the low transfection efficiency of the stem cells.

Conclusion: The primary stem cells and immortalized stem cells were established. The comparison of cell characteristics is ongoing. These cells might be valuable resources for developing cell-based meat in the future.

Future plan: Plasmid and protocol from the current project will be patented, and 1-2 publications will be obtained. The researchers plan to deposit the newly established immortalized cells in the certified cell bank or distributor for future development of cell-based meat.

Laying the Foundation for Cultured Meat Production Towards Food Security in Thailand: The 1st Year Report

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Project duration: 2 years, from 1 August 2022 to 31 July 2024
Current progress: 50%

Abstract:
This research project focuses on advancing cultured meat technology in Thailand, addressing crucial scientific challenges in the emerging industry. Over the past year, the team successfully isolated myoblast stem cells from pig muscles, differentiated them into muscle cells, and developed a hybrid polymer for porcine growth factors, demonstrating enhanced cell growth compared to commercially available counterparts. The study also identified proteins influencing pig stem cell proliferation and differentiation, shedding light on factors that stimulate these processes. Additionally, a three-dimensional myoblast cell culture structure and coated growth factor particles were developed and tested. Collectively, these ongoing efforts collaboratively advance the cultured meat technology platform in Thailand.

Rationales/Problem statements:
Cultivated meat, produced by directly cultivating animal cells, presents a groundbreaking alternative to traditional meat production. Despite its promising potential, the industry is grappling with numerous challenges. The intricate process involves obtaining and cultivating stem cells in bioreactors, guiding their differentiation into meat components. The advantages are substantial, anticipating reduced resource consumption, pollution, and greenhouse gas emissions. However, the journey to market requires overcoming hurdles such as regulatory approval, production scalability, and addressing complexities in cell lines, culture media, bioprocess design, scaffolding, and end product characterization. This technology represents an interdisciplinary amalgamation of scientific disciplines. Research on cultured meat technology in Thailand is in its infancy. Therefore, the objective of this project is to lay a scientific groundwork for the emerging cultured meat industry by tackling significant scientific barriers, bridging knowledge gaps, and fostering the researchers.

Objectives:
This research project aims to develop essential knowledge for creating sustainable and potential protein sources to support the growth of the emerging industry. It focuses on four specific objectives: 1) Developing myoblast cell lines derived from pigs to serve as prototypes for laboratory meat development. 2) Producing growth-promoting substances for myoblast cells and identifying cell growth-enhancing supplements to reduce the cost of cell culture media. 3) Creating bioactive materials and processes conducive to three-dimensional tissue formation. 4) Testing tissue culture in bioreactor systems.

Progress/Findings/Results:
In the first phase, the team successfully produced myoblast stem cells derived from pigs, intending to serve as a foundational model for further developments in lab-grown meat technology. Notably, the team achieved successful isolation of myoblast stem cells with the expression of key proteins, including Pax7, Myosin, and Desmin, demonstrating their capability to differentiate into functional muscle cells. In the second phase, the project focused on the production of growth-promoting substances using a hybrid approach, aiming to identify supplements that could facilitate the cost-effective growth of stem cells. The team developed hybrid plasmids for porcine FGF2, IGF-1, and ActA proteins. Conditions for optimal production of purified porcine FGF2 were established, and the results of culturing myoblast stem cells with these substances showcased promising outcomes. The project also identified specific target proteins influencing the growth of stem cells and compiled a comprehensive list of growth-promoting and differentiating agents for stem cells. In the third and latest phase of the research, the team focused on the development of a 3D structure tailored for cultivating animal tissue in a laboratory setting. The team successfully engineered a 3D framework for cultivating animal tissue in a laboratory, complete with essential physical properties. Additionally, they devised a method for preparing nanocapsules coated with growth factors, contributing to the overall efficiency of the tissue cultivation process. Preliminary results indicated promising survival rates of cells within the 3D framework, and the toxicity assessment highlighted the safety and viability of the developed structure for the growth of muscle cells.

Conclusion:
The successful isolation and differentiation of satellite cells, coupled with the identification of key proteins and growth-promoting substances, lay a foundation for the future of lab-grown meat technology. The development of a 3D structure further enhances the project's potential, offering a platform for the cultivation of animal tissue in a controlled laboratory environment. As the project continues, it not only addresses significant scientific bottlenecks but also contributes valuable insights to the emerging field, paving the way for sustainable and efficient lab-grown meat production. The ongoing work provides a scientific foundation for the cultured meat industry, shaping the trajectory of this innovative field in Thailand.

Current Output: Two manuscripts and two graduate students in the research project

Challenges/Problems and Possible solutions: -

Future plan:
The plan for our 2nd year seeks to advance lab-grown meat technology on multiple fronts. Culturing the cells in a bioreactor will shed light on their impact on myoblast stem cell proliferation. The study aims to evaluate recombinant growth factors' efficacy in fostering tissue-specific stem cell growth, exploring growth-promoting agents' effectiveness. Additionally, the project involves 3D cell integration and the creation of nanocapsules for growth factor encapsulation. Optimal culture conditions for myoblast stem cell yield will be scrutinized. Overall, this research encompasses a multifaceted approach to propel lab-grown meat technology, aiming to refine methodologies and enhance key elements for future applications.

Development Towards Authentic Cell-based Meat Replicating High-Value Regional Specialty Animals Using Cellular Agriculture: A Case Sudy of *Tor douronensis'* Meat

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Project duration: 2 years, from 1 April 2023 to 31 March 2025
Current progress: 20%

Abstract: This report outlines the progress of a pioneering project aimed at developing cell-based meat alternatives by replicating high-value fish species using advanced cellular agriculture techniques. We sourced *Tor tambroides* and *Tor douronensis* and are optimizing cellular extraction and culturing conditions derived from fish tissues. We are employing advanced imaging to analyze fish tissue structure. Secondly, we are developing biocompatible and edible scaffolds that mimic fish skin by cellulose-based electrospinning and muscle texture by soy-protein-based freeze-drying. Using advanced imaging and spectroscopy techniques, we are developing techniques to link the microscale elasticity in 3D scaffolds to their macroscale tactile properties. Challenges remain, particularly in primary cell culturing, balancing scaffold composition for optimal biocompatibility, and determining mechanical properties through scaffold expansion, but our progress is encouraging. This comprehensive approach encapsulates our dedication to advancing cellular agriculture technology.

Rationales/Problem statements:

Global warming accelerates the degradation of natural ecosystems and threatens species extinction. Thailand adopted the BCG Economic Model by developing its National BCG strategic plan 2021-2026 to address the challenge of preserving its rich biodiversity, essential for economic development. Agricultural expansion, industrial development, and illegal wildlife trade jeopardize Thailand's diverse ecosystems, species, and genetic wealth. To align with the National BCG strategic plan, Initiative 4.1, Program 1, we are developing cutting-edge technology to cultivate meat in the lab. Additionally, to follow Initiative 4.2, Program 1, we are producing skilled manpower in cell culture and relevant technologies, crucial for developing novel food industries. Foreseeing an opportunity for producing meat from cells of locally significant, economically valuable, and potentially endangered Thai species, we propose a case study involving the high-value, challenging-to-cultivate *Tor douronensis* and aim to develop an appropriate platform for leveraging Thailand's biodiversity strengths, per both mentioned Programs.

Objectives:

1. To study the optimal conditions for primary cells extracted from fish tissue to function as satellite cells, which can easily transform into key muscle cell types.
2. To develop and screen suitable edible scaffolds for producing fish meat from cultured cells.
3. To develop techniques linking the microscale elasticity in 3D of the scaffolds to the macroscale tactile properties, using X-Ray Tomography, Atomic Force Microscopy, and Fluorescence Microscopy.

Progress/Findings/Results:

In our multifaceted project, we made some progress across three key objectives. Firstly, we obtained the cost-effective *Tor tambroides* and the pricier *Tor douronensis* for our cell culture studies. We conducted various digestion experiments on their muscle and fin tissues through multiple trials. We examined the structural morphology of *Tor tambroides*'s muscle in 3D to enhance our scaffold design and growth medium optimization. Our efforts also included an extensive literature review and the development of an AI model aimed at optimizing cell feed formulas, particularly focusing on myoblasts and myosatellite cells to prolong their lifespan and increase proliferation.

Secondly, we innovatively created 2D and 3D scaffolds that mimic fish skin and meat using cellulose, electrospinning, and freeze-drying techniques, incorporating materials like soy protein and biopolymers. We used gelatin mixed with Hydroxyapatite (HAP) and calcium phosphate, surface-treated with L-Alanine for fish skin imitation. These scaffolds underwent comprehensive testing, including biocompatibility with mouse osteoblasts, revealing enhanced cell adhesion. We also explored cellulose acetate in 2D configurations. We discovered that higher soy protein content in freeze-dried 3D scaffolds obtained by mixing with konjac and gellan gum improved mechanical properties but increased toxicity, necessitating further research.

Lastly, our third objective focused on connecting the microscale elasticity of these scaffolds to their macroscale tactile properties. We employed techniques like X-ray tomography, Atomic Force Microscopy, and Fluorescence Microscopy for this purpose. Our method involved selecting porous samples for direct property analysis, obtaining the microlocal stiffness data, and developing a 3D mapping algorithm to integrate this data into our AI system, aiding in scaffold analysis and design optimization.

Conclusion:

We experimented with satellite cellular extractions with affordable and premium fish species, examining tissue structure and formulating various culture media. Our focus on scaffold design, using advanced techniques like electrospinning and freeze-drying, has led to promising results in mimicking fish skin and meat. We are linking the scaffold microscale elasticity to tactile properties, employing cutting-edge technologies like X-ray tomography, AFM, and Fluorescence expansion.

Current Output:

The manuscript for review article tentatively entitled “In vitro fish cell culture: primary muscle cells to cell-based meat in Cyprinidae”

Challenges/Problems and Possible solutions:

Our major challenges lie in primary cell culturing. We found inherently severe microbial contaminations, and it is currently difficult to obtain live cells, so we are trying it with stronger antibiotics and plan to increase the condition-optimization trials and approaches.

Future plan:

Despite our grand vision plan, we are focusing on addressing the abovementioned challenges.

BRAINPOWER CONGRESS 2023
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ด้าน Global Partnerships (ASEAN Talent Mobility, Environment)

Co-Creating Sustainable Transformations of Food Supply Chains Through Cooperative Business Models and Governance

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Project duration: 3 years, from 1 April 2023 to 31 March 2026
Current progress: 30%

Abstract:
Climate change, the COVID-19 pandemic, and the wars reveal unsustainable features of conventional, globalized food supply chains. Various efforts have been undertaken to transform food supply chains (FSC) towards sustainability. Cooperative business models adopt many of these sustainable practices. Yet, there is little empirical, comparative research on how to implement sustainable food supply chains (SFSC) through cooperative models. Research suggests the need for rapid implementation of sustainable agri-food systems solutions. Co-SFSC coordinates transdisciplinary research across five research "hubs" in Turkey, Thailand, Taiwan, Sweden, Germany and the U.S., building a Community of Practice for mutual learning. The research "hubs" co-create knowledge, visions, plans and small-scale experimentations on how to innovate, convert, and strengthen FSC in different socio-cultural-political contexts. For Thailand hub, researchers focus on restaurants cooking and serving organic foods, as a potential channel to promote organic food consumption, which can further drive organic food production in Thailand.

Rationales/Problem statements:
The development of local organic production and consumption in Thailand face many challenges throughout the supply chain. Organic farmers heavily involve in not only in production, but also transportation and retail activities. Thai consumers have limited choices because could only access for organic produces from specialized stores, selected supermarkets, and local weekend markets. Most of food that consumers could select from these channels were fresh produces, which only fitted one food consumption practice – dining at home. At the moment, there are only few restaurants serving organic foods. This situation leaves a gap to improve for promoting organic food consumption since eating out is one of the most predominant food consumption practices for Thai consumers, especially urban consumers and tourists. This study amins to evaluate the current state of sustainability (baseline), to explore future visioning of sustainable restaurant SFC, and to identify strategies for transition for more sustainability of restaurant SFC.

Objectives:
(1) To evaluate the sustainability of the current state of organic food supply chain in the study area
(2) To explore the visions of key stakeholders (farmers, restaurants, consumers) on sustainable food consumption
(3) To develop strategies and action plans to achieve mutually compatible visions of SFSC

Progress/Findings/Results:
The researchers employ scoping review to ensure that all sustainability criteria are covered and specific to the context of restaurant supply chain. We began searching for research articles in the Sciences Direct, Scopus and Google Scholar. The searches used the keywords: "sustainability assessment" AND "evaluation criteria" AND "food supply chain". There are three inclusion criteria. The first criterion was the inclusion of studies presenting sustainability criteria that are applicable to the restaurant supply chain. Secondly, we

identified at least one criterion (economic, environmental, social) that can be used to evaluate the sustainability of the restaurant supply chain. Thirdly, because this research employs qualitative evaluation, only articles presenting qualitative evaluation criteria were included. Finally, 16 articles were read in full and assessed. The result found that the evaluation criteria included economics (economic viability for providers, consumers' affordability), environment and health (food miles, reduction of energy consumption, waste reduction, efficiently use of water, certification, biodiversity adoption of eco technology, food safety, environmental justice), and social and culture (good governance, relationship between actors, equity, and culture). The details of these criteria are explained and adjusted to Thai context by interviewing 4 experts/ stakeholders. After that, the researchers made list of questions in accordance of the criteria.

The in-depth interview is conducted with 20 organic farmers, restaurants serving organic foods in Bangkok and Metropolitan Area (BMA) and Phuket, and related agencies in order to assess the current sustainability. For economic aspects, the restaurants and farmers in BMA attempted to share their demand and supply as well as to pre-order the organic products with the pre-determined price. Most of farmers in BMA work as a group so they can plan and negotiate for the price. However, the restaurants and farmers in Phuket were different. They attempted to communicate and pre-order the products but were unsuccessful. The farmers in Phuket are working as individual and they were reluctant to commit for pre-order because they are afraid that they cannot supply due to climate uncertainty. The restaurant in Phuket also mentioned that it is difficult to find organic products from local farmers because Phuket is a tourist area and has limited land for agriculture. In terms of environmental aspects, the restaurants and farmers tried to minimize waste by recycling the materials and making fertilizer from food waste. They also purchased materials from local stores because it is cheaper not because they concern about food miles. Some restaurants used degradable food containers. Most of farms were certified by PGS organic and organic Thailand standard. However, the consumers did not pay attention much on environmental aspect because they more care about their health and only want to know whether the food is really organic or not. For the societal aspects, the farmers, restaurants, and consumers tried to communicate and build trust with each other. This is done by farm visit, market event, and Facebook communication. We also found that the farmers and restaurants attempted to promote traditional food by growing traditional vegetable and creating traditional menu to the consumers.

Conclusion:

From the interview, we can conclude that the restaurants in BMA and Phuket met the sustainability criteria in terms of price fairness and affordability, waste minimization, and communication with other stakeholders in food supply chain. However, there are still some criteria that need to be improved such as local recruitment, biodiversity, energy saving, animal welfare, gender balance, eco-package, and water recycling.

Current Output: 6 months progress report

Challenges/Problems and Possible solutions: -

Future plan:

The researchers will conduct visioning workshops and transition workshops with stakeholders in BMA and Phuket.

International Collaboration Project on Developing a Computational Engineering Multidisciplinary Research in Blast Modelling and Experiment

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 60%

Abstracts:
The Faculty of Engineering, Mahidol University has gradually developed into one of the most prestigious engineering faculties in Thailand. It has been known and recognized by outstanding achievement in international research collaboration. The goal of this global partnership collaboration is to create a multidisciplinary research via in-depth knowledge exchange among international networks. This partnership collaboration provides technology transfers to support excellent manpower in Mahidol University including long-term advanced technology development in Thailand from computational engineering research. In addition, this collaboration could encourage and elevate Thai researchers to be global talent in the future. In this partnership collaboration, a computational engineering multidisciplinary research of Finite Element Analysis (FEA) modelling in solid mechanics and Computational Fluid Dynamics (CFD) modelling in particle flow is proposed for a starting research topic of blast modelling.

Rationales/Problem statements:
Thailand has been facing many rapid changes including changes in internal and external threats in terms of national security. Homeland security is an important issue to be considered due to various unexpected reasons, such as explosions, terrorist attacks, gas leaks, and industrial accidents. Therefore, systematic research from fundamental to practical is necessary to reduce the consequent impact of the explosion for public safety. Since blast modelling is a complicated phenomenon of extreme conditions, there is a research gap in enhancing protective design criteria of public structures for both aspects of civil and mechanical engineering. The purpose of this research is to study explicit blast modelling and field experiments for investigating possible phenomena and to improve explosion mitigation measures. The outcome of this research could help to enhance security capacity to prepare for blast threats that might affect public safety in the future.

Objectives:
1) To create global partnership collaboration with in-depth knowledge exchange in computational engineering multidisciplinary research.
2) To elucidate the fundamental physics of wave propagations through experimental observations and assess the capability of up-to-date numerical modeling.
3) To address a detailed understanding of structural behaviors for buildings subjected to blast loading through a solid mechanism paradigm integrated with computational fluid dynamics.
4) To investigate the blast phenomenon's consequences, including protective building design, harmful particles, noise emission, and thermal comfort, which are disruptive to public safety.

Progress/Findings/Results:

The simulations of localized blast on the X70 pipeline have been performed and discussed along with the experimental data. The dynamic response of local blasting loads on pipe surfaces was investigated using a numerical approach named LS-Prepost (LS-DYNA). Overall, four failure types of carbon pipelines were observed, and the findings show that wall thickness and charge mass are crucial factors in the pipeline's deformation. According to this investigation, the conclusions of the validation study can be drawn as follows.

- The contact area is related to the deformation range as a significant effect.
- The pipeline deforms inelastically when the explosive mass is minimal. On the other hand, the pipeline faces adiabatic shearing failure when the explosive energy is significant enough.
- The displacement of the pipeline following a failure is also observed. The fragment formed during the experiment has tremendous kinetic energy, and it has the potential to pull the back zone apart.

Nevertheless, the simulation may require further observation, especially to capture the motion of the fragments after tearing it apart in future work. Particularly, the estimation of the blasting force or its destructive power damage of explosive material pieces could be gained and guided to the engineering purposes, for instance, in terms of building structure design and such prevention applications.

Conclusion:

The empirical formula and LS-DYNA simulation using FSI methods are both effective in studying blast pressure problems. By comparing the results from both methods to the experimental data, we found that LS-DYNA simulation provides a more accurate prediction of the blast wave's velocity and pressure distribution. The transient pressure plot obtained from the simulation graph is also an effective tool for understanding the blast wave's behavior over time. With the use of LS-DYNA's ALE-Multimaterial FSI tracking capability, we were able to accurately simulate the blast wave's propagation and observe the blast wave's interaction with the pipe structure. Furthermore, we were able to identify the optimal geometric modifications for large pipes that can enhance their mechanical properties and resistance to blast wave propagation.

Current Output:

1) Bonding behavior of interface between reinforced concrete after fire and carbon fiber-reinforced polymer, *Construction and Building Materials*, 382, 131289

2) Investigating the Multi-Physics Dynamics of TNT Charge 2 Fragmentation: The Role of Pressure-Induced Deformation 3 and Characterizing the Splash of Fragments, *Heliyon* (In review)

3) Experimental Elucidation of Dynamic Response of Unconfined Semi-Confined and Fully Confined Blast Pipes: Empirical Prediction of Circular Plate Deflection (In preparation)

Challenges/Problems and Possible solutions: -

Future plan:

- Incorporating the underlying physics of blast insight into construction material and structure retrofit technology
- Investigating mechanisms to enhance protective building design criteria
- Optimizing evacuation plan under fire and smoke emergency in a public building
- Predicting thermal comfort criteria for a public building in case of emergency

Development of Flexible Conductive Substrates for Energy and Sensor Applications

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 70%

Abstract:
The key focus of this research project is to integrate the expertise related to fiber science, electroplating, and electroless plating technique for developments of conductive flexible substrates that will be applied for high performance energy storage device (e.g., battery) and high efficiency chemical sensor (e.g., electrochemical sensor). The research activities include selection and modification of potential fibers, metallization for formation of conductive fibers/substrates, and fabrication of energy storage and electrochemical sensor devices and systems which ultimately contribute to the society's sustainable developments in various aspects. With the supports from PMUB under program 16, the research team's capabilities are enhanced through collaborations with the international experts in the area of fabric science and surface coating technology.

Rationales/Problem statements:
Flexible conductive substrates are a class of materials that can conduct electricity while conserving their physical properties upon stretching or bending. In the past, metals or alloy had been processed into a very thin or extremely long shape soft metal electrode so that they were flexible. However, the properties of metals and alloys might be changed upon their physical shapes and strongly depend on their characteristics, which might be difficult to fine tune to a specific application. The progress in chemistry and material science has accelerated the development and production of novel conductive flexible materials for various applications, leading to the expansive field of the flexible electronics. Nevertheless, there are big rooms for further development in this field, including fabrication of conductive substrates based on local fabric, as well as advancement of conductive substrates for healthcare and energy applications.

Objectives:
- To co-develop the high performance of flexible conductive substrates for energy and sensor applications
- To strengthen the collaboration between Chulalongkorn University, Fraunhofer Institute IPA (Germany) and Cornell University (USA)
- To exchange the knowledge and expertise between the researchers and groom the young generation to be the experts in flexible conductive substrate research field

Progress/Findings/Results:
Overall, the research has been conducted according to the plans. Natural fibers, particularly silk and cotton, has been explored for developments of conductive and flexible substrates, particularly for bio-chemical sensor applications. The enhancement of cellulose nanofiber has also been investigated with the inclusion of hydrogel for improvement of sensing-ability. Furthermore, nickel and zinc-based electrode fabrication processes have been investigated on substrates such as cotton cloth for possible applications of energy storage and catalysts for hydrogen evolution reaction. The research works encompass surface treatment of substrate materials (e.g., fiber), metal deposition, and microstructural and property characterization.
Silk based conductive flexible substrates were created as the working electrodes for electrochemical sensors offering the biocompatibility and human skin friendly with low

preparation cost. The silk cocoon and silk fabric surfaces were carbonized and modified by electrodeposition and chemical reduction to obtain Pt and Au nanocomposites with silk, respectively. The as prepared silk nanocomposites offered homogeneous deposition of metallic nanoparticles on the surfaces with high conductivity and electrocatalytic property leading to potentially high sensor performances. Furthermore, this platform provides value-added to silk cocoon and silk fabric and make them as the smart flexible substrate materials for wearable sensor applications. Particularly, PtNPs/rGO deposited on carbonized silk has a high potential to be used as flexible bioelectrode for wearable sweat lactate sensors due to the excellent cytocompatibility combined with the outstanding electrochemical sensing performance, whereas the modified conductive fiber has a high potential for applying in high-performance energy storage, electrochemical sensors, and LDI-MS. In another part of works, synthesizing of PANI/CNF nanocomposite and fabricating of PANI /CNF/PVA hydrogel modified on SPE by in situ chemical polymerization and freezing-thawing method have been conducted successfully. The effect of ANI and CNF concentrations was investigated. The study demonstrates promising performance of the modified cellulose nanofiber for heavy metal detection applications.

Furthermore, an investigation on cotton cloth for electrode development for battery applications has been successfully conducted. The cotton was treated with electroless deposition of nickel phosphorus, and subsequently electrochemically deposited with zinc metal. To increase the Zn deposition efficiency, the surface of conductive cloth is further modified by Sn, CuSn, and $ZnIn_2S_4$, which can modulate the Zn^{2+} plating/stripping. ZISG-decorated CC was developed to act as the flexible Zn host for high-performance AZIBs. The obtained symmetric cells under investigation are characterized by outstanding flexibility, a longer lifespan, a satisfactory long-term cycling performance with high discharge capacity and high capacity retention.

Finally, electroplating of Ni alloy, specifically NiW, has been examined as electrocatalysts for hydrogen evolution reactions (HER). The developed porous and 3D flower-like coating shows high active sites and thus improvements of the HER activity. The study provides a new and effective strategy for further improvement of the catalytic performance of NiW electrocatalysts.

Conclusion:

Various flexible conductive substrates and metallization techniques have been successfully explored and developed in this study, including PtNPs-rGO deposited silk cocoon and AUNPs modified silk fabric both for biochemical sensor application, PANI/CNF/PVA hydrogel on cellulose nanofiber for heavy metal sensor, Ni/Zn fiber for battery application, and NiW plating for HER electrocatalyst. As these studies have provided fundamental understanding on how flexible conductive substrates can be effectively fabricated, and how process parameters affect their performances, the research is moving forward to development of useful devices and systems based on these flexible conductive substrates and metallization techniques.

Current Output: 8 published articles (5 Tier-1; 1 Q-1; 2 Q-2)

Future plan:

Fabrication of sensor and energy storage devices based on the developed flexible conductive substrates and the gained knowledge, and study them in the environments close to actual usage conditions.

The Study of Expertise and Academic Capability of ASEAN Talents

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Project duration: 1 year, from 16 August 2022 to 15 August 2023
Current progress: 100%

Abstract:
The Program Management Unit for Human Resources and Institutional Development, Research, and Innovation (PMU-B) spearheads a transformative initiative propelling the nation into global prominence in science, technology, research, and innovation. Focused on artificial intelligence, quantum, Earth and space sciences, high-energy physics, and Bio-Circular-Green Economy, the project fosters international partnerships, identifies top researchers, and leverages SciVal data for strategic insights. The research, based on ASEAN academic landscapes, highlights Indonesia's AI prowess, Malaysia's quantum leadership, and diverse strengths in Earth sciences. Thailand excels in high-energy physics, positioning itself as a hub. Malaysia and Singapore shine in the Bio-Circular-Green Economy, each with unique emphases. These findings, drawing from expert opinions and SciVal metrics, offer a comprehensive view, informing collaborative initiatives and policy decisions for ASEAN's sustained research and innovation progress.

Rationales/Problem statements:
The Program Management Unit for Human Resources and Institutional Development, Research, and Innovation (PMU-B) has initiated a strategic effort to propel the nation to the forefront of global advancements in science, technology, research, and innovation. This initiative centers on developing future industries through the creation of technologies and innovations, fostering opportunities, and enhancing the country's preparedness for the future. Concurrently, emphasis is placed on nurturing expertise in science, research, and innovation, with a transformative focus on elevating research institutions into high-level hubs that catalyze sustainable economic and societal development.
This research project specifically targets cutting-edge global research areas: (1) artificial intelligence, (2) quantum, (3) Earth and space sciences, (4) high-energy physics, and (5) Bio-Circular-Green Economy. Aligned with PMU-B's commitment to fortify the nation's innovative capabilities, the researchers advocate a global strategic partnership. This entails cultivating research collaboration networks through joint funding initiatives, establishing fellowships for high-level researchers, and collaboratively developing technologies, innovations, and research institutions with international partners. Such a strategic approach will play a pivotal role in analyzing and synthesizing data for policy formulation, direction-setting, and workforce production strategies to navigate the rapidly evolving technological landscape and business paradigms.
The project will identify high-potential researchers through indicators such as citations from published research articles, citation indices, the overall number of citations, and the number of collaborators within the cutting-edge research groups. This selection will be based on data gathered from the SciVal database, considered suitable for analysis to inform academic policy decisions, aiming to pinpoint strengths and opportunities for Thailand's ongoing development concerning its ASEAN counterparts.

Objectives:
Leveraging the SciVal database, systematically interrogate significant researchers and their

associated research metrics across the ASEAN countries over the preceding decade, focusing on diverse frontiers in research and technology.

- Employing comprehensive quantitative and qualitative statistical analyses, meticulously examine the interrelationships among authors, their pertinent metrics, and accompanying parameters. The aim is to delineate meaningful insights that can inform potential policy applications in the academic domain.
- Convening focused groups comprised of subject matter experts within each respective field to authenticate and validate the integrity of the queried data, thereby fortifying the reliability of the research outcomes.

Progress/Findings/Results:

The completion of this research has yielded noteworthy results and findings in our exploration of the academic landscape of ASEAN researchers. Through the systematic extraction of performance metrics from SciVal, we scrutinized the achievements of researchers across five critical frontier fields: artificial intelligence, quantum, Earth and space sciences, high-energy physics, and Bio-Circular-Green Economy.

The collected data has provided valuable insights, encompassing the identification of prominent researchers in each field, the extraction of country-specific research keywords, and the invaluable perspectives obtained from experts during our focus group sessions. These results not only contribute to a quantitative assessment of researcher performance but also add qualitative depth through expert opinions. In the domain of Artificial Intelligence (AI), a total of 760 authors have made substantial contributions, with Indonesia emerging as the primary publisher. The academic strengths in AI exhibit a hierarchical pattern, with Singapore leading, followed by Malaysia and Thailand. Unique patterns in keywords reflect diverse research emphases across ASEAN countries. Within the field of Quantum research, involving 2,940 authors, Malaysia stands out as the leading contributor. Singapore demonstrates the highest academic strengths, followed by Thailand and Malaysia, showcasing a predominant focus on quantum materials science. Earth & Space Sciences engage 983 authors, with Indonesia leading in publications. Thailand emerges as a significant academic force, followed by Singapore and Malaysia. Notably, two distinct clusters have been identified, encompassing Astronomy and Earth science.

High-Energy Physics, involving 493 authors, sees Thailand leading in publications. Academic strengths in this field are prominently displayed by Thailand, followed by Malaysia and Singapore. Two substantial clusters have been observed, involving experimentalists and theorists. In the Bio-Circular-Green Economy (BCG) domain, 4,065 authors contribute, with Malaysia standing out as the primary publisher. Singapore showcases the highest academic strengths, followed by Thailand and Malaysia. Notably, Malaysia's emphasis is on materials technology, while Thailand focuses on bio-based/medical research, potentially positioning itself as a "Medical hub."

Collectively, these findings offer a vivid portrayal of the diverse and evolving academic landscape within the ASEAN region. The insights derived from this research provide valuable information regarding strengths, trends, and potential strategic directions for future collaborative initiatives. As we conclude this research, the depth of understanding gleaned from these results stands poised to inform strategic decisions, collaborative endeavors, and policy formulations for the continued advancement of research and innovation in ASEAN.

Conclusion:

In conclusion, the completion of this research is a significant milestone in comprehending the academic landscape of ASEAN researchers. Through meticulous SciVal querying, we explored performance metrics across pivotal fields, uncovering insights into prominent researchers, country-specific keywords, and expert perspectives. This endeavor contributes

quantitatively and qualitatively, advancing our understanding of ASEAN's academic capabilities. The amalgamation of findings serves as a foundation for future collaboration, innovation, and strategic positioning in cutting-edge research. As we conclude, these insights will inform policy decisions and academic strategies, enhancing the global standing of ASEAN talents in these frontier fields.

Current Output:

Research database and analytics models.

Challenges/Problems and Possible solutions:

Future plan:

Several actions can be taken to effectively utilize the results of this study. One such action involves assessing the research output and innovation culture within academic institutions. The aim is to identify barriers to research and propose strategies for fostering a culture of innovation and entrepreneurship. Additionally, there is a need to explore opportunities for cross-border collaboration among ASEAN countries, leveraging each other's strengths in education and expertise development. This entails the development of frameworks for collaborative research projects and initiatives such as staff and student exchange programs.

ASEAN BCG Researcher Development Program 2023

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Project duration: 1 year, from 28 August 2022 to 27 August 2023
Current progress: 100%

Abstract: The Bio-Circular-Green Economic Model or BCG has been introduced by the research community and promoted by the Thai government as a new economic model that supports inclusive and sustainable growth while reducing waste, pollution and dependence on finite resources. In January 2022 the ASEAN BCG Network was launched which is a coalition of public, private and non-government organizations in ASEAN committed to BCG and who are focused on building capacity in research, development and technology diffusion to enable the adoption of applicable technologies for sustainable development. The network will serve as a gateway to catalyze collaboration with other non-ASEAN organizations in research, technology demonstration, technology localization and commercialization on BCG.

Rationales /Problem statements: One of the strategies outlined in the ASEAN Plan of Action on Science, Technology, and Innovation (APASTI) 2016-2025 emphasizes the importance of developing individuals within ASEAN through personnel exchanges and network establishment. This initiative aims to foster collaborative development, address critical global challenges, and work towards achieving Sustainable Development Goals (SDGs). The BCG Model aligns with the Sustainable Development Goals (SDGs), requiring collaboration among experts from all sectors—governmental, private, and international networks—to achieve these objectives. Therefore, establishing a network of experts in science, technology, and innovation in ASEAN to promote economic development, trade, and investment in line with the BCG Economy Model through the practical ASEAN BCG Researcher Development Program is a means to prepare and elevate the capabilities of personnel in science, technology, and innovation in ASEAN. This initiative aims to strengthen individuals, foster progressive thinking among leaders, and create a supportive network to advance the economy in ASEAN. It utilizes science, technology, and innovation aligned with the principles of the BCG Economy Model.

Objectives:

1. To foster a new generation of research personnel in ASEAN (ASEAN Talent Researchers) equipped with essential skills for networking and ascending as forefront researchers in both their countries and ASEAN.
2. To foster networking among researchers in ASEAN, aiming to collaborate advancing research projects to seek funding from international sources such as ASTIF, GCF, and Belmont Forum.
3. To support knowledge exchange between organizations in the ASEAN region and establish mechanisms supporting Talent Mobility.
4. To provide opportunities for ASEAN regional organizations to recognize the benefits of utilizing science, technology, and innovation for economic development.

Progress Findings/Results:

The project "ASEAN BCG Researcher Development Program," aimed primarily at creating a network and nurturing a new generation of research personnel in ASEAN in the field of BCG development, had the main objective of organizing a curriculum to develop skills

crucial for the region. These skills include proposal writing, research presentation, among others. The project comprised two phases: Phase 1 encompassed nine rounds of online training sessions (February - April 2023) with 1,407 registered participants. Phase 2 involved selecting candidates who successfully passed the Phase 1 evaluation, totaling 20 individuals, including 10 Thai researchers, resulting in a total of 30 participants. engaged in practical training in Thailand from 10 – 14 July 2023. The curriculum of the project in Phase 1 was divided into 9 sessions:

1. ASEAN Foresight and Sustainable Development Goals (SDGs)
2. Communication
3. Critical thinking and creativity
4. Management
5. Collaboration
6. Journal Writing
7. Proposal Writing for International Funding
8. Scientific Presentation
9. Strengthening Networking Skills

Phase 2 conducted practical training from 10 - 14 July 2023, at the Century Park Hotel in Bangkok. The 30 participants were divided into 4 groups, and each group had a mentor to provide guidance and serve as a consultant during group work. Details of the breakdown are summarized below as follows:

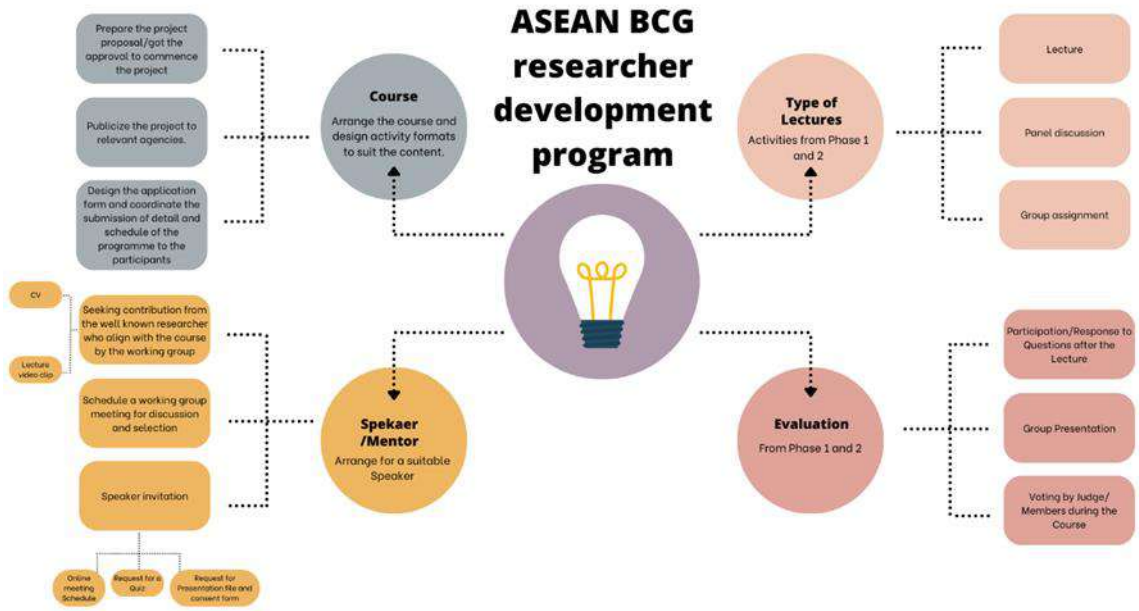
1) Agriculture and Food has 8 participants – 5 from Thailand and 3 from Singapore, Vietnam, and Indonesia. Mentored by Prof. Dr. Hanilyn Aguilar Hidalgo from Central Bicol State University of Agriculture, Philippines.
2) Medical and Wellness has 7 participants – 4 from Thailand with 2 from Malaysia, and 1 from Indonesia. Mentored by Assoc. Prof. Dr. Sorada Kanokpanont, Biomaterial for Medical and Health Research Unit, Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University
3) Energy, Material, and Biochemicals has 7 participants – 3 from Thailand with 2 from Malaysia, 1 from Indonesia, and 1 from Vietnam. Mentored by Dr. Eng. Deni Shidqi Khaerudini, Research Professor, Research Center for Advanced Materials, National Research and Innovation Agency (BRIN), Indonesia.
4) Sustainable Community has 8 participants – 2 from Thailand with 2 from Malaysia, 2 from Philippines, and 2 from Vietnam. Mentored by Dr. Kuok Fidero, Director General, National Institute of Science, Technology and Innovation, Ministry of Industry, Science, Technology and Innovation, Cambodia**.**

The program is divided into 5 main topics, presented through lectures, explanations of examples/best practices, followed by assigning presentation tasks to groups/individuals based on activities outlined:

- **Day 1** Research and Opportunities for Collaboration in ASEAN (Instructor: Mr. Hernandi Dwi Prasetyo, ASEAN Secretariat (ASEC), Programme Cooperation and Project Management Division (PCPMD)
- **Day 2** International Funding Opportunities (Instructor: 1. Dr. Jenny Lind Elmaco, Regional Coordinator, EURAXESS 2. Ms. Emi Kaneko, e-ASIA Secretariat / JST Singapore Office 3. Asst. Prof. Dr. Worajit Setthapun, Deputy Director, PMU-B)
- **Day 3** Writing an International Grant Proposal (Instructor: Dr. Brian Cahill
- Leibniz Information Centre for Science and Technology)
- **Day 4** Scientific Communication (Instructor: Ms. Perada Suponpun, Chief Executive Officer, Tasted Better (Thailand) Limited and site visit to NSTDA

- **Day 5** Pitching (Instructor: Ms. Perada Suponpun, Chief Executive Officer, Tasted Better (Thailand) Limited

Conclusion (Maximum 100 word):



Current Output: Curriculum or Training Course with list of topics and potential speakers/experts

Challenges/Problems and Possible solutions:

Challenges/Problems

1. The registered participants exceeded the project's expectations, which exceeded the capacity of the online seminar system.
2. The session topics do not cover the interests of all participants.
3. Applicants do not meet the criteria regarding age and ethnicity, but they show a keen interest in participating in the activities.

Possible solutions

1. Conduct a survey to gauge interest in the activity to assess the number of registrations and prepare alternative online channels for organizing the event.
2. Raise awareness for BCG concepts to help researchers connect with relevant studies, gain insights for designing related projects and presenting proposals to funding agencies supporting SDGs-related research. Expand the range of topics accepted within the project and identify suitable entities, such as those in the Social Sciences, to oversee them.
3. Expand activities that can engage with all researchers, Early, Mid, and Senior levels, as well as expand the scope to include researchers from beyond the ASEAN region.

Future plan: Engaging with the ASEAN Talent Mobility Community (ATM) involves gathering data about new-generation researchers in the ASEAN region to foster future collaborations (Talent Warehouse). This activity strengthens competency skills, enhances individual capabilities for research collaboration, and expands work with international institutions. As an extension, it enables personal-level activities, inviting participants to engage in suitable activities and showcase their research. For instance, those who excelled in Phase 2 training as the 1st and 2nd Best Presenters were invited to pitch at the ASEAN BCG Competition Awards in August 2566. This ongoing effort contributes to personnel

development by providing scholarship recipients with opportunities to demonstrate their abilities and contribute to future collaborations. Furthermore, collaborating with external partners, known as dialogue partners, holds significance due to the broad scope of work and the budget allocated to support research. This attracts new-generation researchers to be interested in writing project proposals and contributes to driving human resources by encouraging mutual interest in collaborative work.

Talent Utilization Platform for ASEAN Talent Pool

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Project duration: 1 year, from 16 August 2022 to 15 August 2023
Current progress: 100%

Abstract:
The dataset of high-potential researchers comprises 8,220 individuals, with a total of 26,513 research keywords. This data, which spans a 10-year period from 2012 to 2021, includes the dissemination of research articles. The top three ASEAN countries in terms of research publication are Malaysia with 38.7%, Thailand with 25.2%, and Singapore with 24.6%. The highest publication rates are found in two industry groups: BCG and Quantum. BCG, an industrial group, focuses on developing research topics in three sub-categories: 1) Bioeconomy, 2) Circular economy, and 3) Green economy. The leading countries in research and dissemination focus on sustainable economic development and on advancing modern technologies, such as Quantum, which is a fundamental theory in physics and a technology poised to revolutionize the world.

Rationales/Problem statements:
This project is established as a platform to enhance collaboration in research and innovation in Science and Technology within the ASEAN region. It primarily aims to connect high-potential talent in ASEAN with emerging opportunities in Science, Technology and Innovation. The core principle of the project is creating a central hub of information and networks for ASEAN Talent and Industry Sector. Through these connections, the project aspires to generate new opportunities for collaboration, leading to innovations and advancements in science and technology.
The ASEAN Talent Platform Project represents a significant step towards a bright and innovative future for the ASEAN region. It is a crucial element for the region's growth and sustainable development.

Objectives:
1. Gather and analyze data on high potential manpower in alignment with the Global Frontier Research group (AI, Quantum, Earth & Space, High Energy Physics) and BCG in the ASEAN level.
2. Analyze, design, and develop a system for statistical data processing and dissemination of information on high potential manpower in line with the Global Frontier Research group and BCG.

Progress/Findings/Results:
The research methodology consists of the following 4 steps:
Step 1. Business Understanding.
The research team has participated in meetings and/or activities with the project studying the expertise and academic potential of outstanding researchers in the ASEAN countries. Meetings were held with PMU-B to gather requirements and study from the research policy documents of PMU-B and ASEAN countries.
Step 2. Design a research collaboration platform.
The processes in these steps are data gathering and data preparation.
Step 3. Implementation

In this research study step, data analysis will be conducted on the dissemination of articles, selecting a model for analyzing data on high potential manpower in ASEAN, and then designing a platform, installing, and tuning the performance of the system.

Step 4. Deployment and Conclusion.

Implementing the prototype of the ASETAN Talent Mobility platform in a trial with various user groups, such as national policy groups, researchers, industries, and the platform management team.

The data collection goal of ASEAN Talent in phase 1 focuses on gathering data from five industries, with ASEAN Talent percentages in the BCG group at 42%, Quantum at 35%, AI at 9%, Earth and Space at 9%, and High Energy Physics at 5%. From this data, it is observed that in 2021, researchers from the 10 ASEAN countries published articles on BCG and Quantum the most, ranking first and second respectively.

From summarizing the basic statistics and looking at historical data, it is found that the H-index values of ASEAN Talent in all five industry groups are similar, namely AI, BCG, and High Energy Physics, with an average H-index in the range of 15.9-18.7. Quantum has the highest average H-index in the group, and Earth and Space have the lowest average H-index. Even though the High Energy Physics group has the smallest percentage of ASEAN Talent at 5% among the five groups, it is found to have the highest Citation count, with a Citation Count of 5,902.6. When performing cluster analysis, it can be divided into 3 groups. In the remaining four industry groups, it is possible to divide them into four clusters.

Conclusion:

This study focuses on the reveal of ASEAN Talent from five target industries to understand the 'Know Who?' aspect. Using data analytics, specifically descriptive and diagnostic analytics, the study explores the relationships and distribution of ASEAN Talent. It also involves grouping them according to performance based on the publication of research articles over the past 10 years. This is beneficial for the ASEAN community in building collaborative research efforts and jointly determining research directions, aiming to create an impact for the ASEAN group in the future. The ASEAN Talent Mobility (ATM) is a part of driving the research initiatives of ASEAN.

Current Output:

ASEAN Talent Mobility platform is the output of the research project Talent Utilization Platform for ASEAN Talent Pool.

Challenges/Problems and Possible solutions:

The challenge of developing the platform is to generate traffic for the platform, and to create sustainability in managing the platform to be beneficial both now and in the future.

Future plan:

The future development plan for ATM includes the enhancement of functions to meet the system users' needs, such as the creation of a Matching system and Recommendation system to facilitate collaborative research. Additionally, there is a desire for ATM to become a web portal that can link the research work of each country through various online channels. This includes being a hub for knowledge sharing and evolving into a Think Tank for ASEAN in the future.

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ด้านการพัฒนากำลังคนทักษะสูง (Industrial/Frontier Postdoc) ด้านเกษตรอาหารและการแพทย์

Postdoctoral and Postgraduate Platform for BCG Economy and Frontier Technology to Drive Thailand Industry

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 80%

Abstract:

The project "Postdoctoral and Postgraduate Platform for BCG Economy and Frontier Technology to Drive Thailand Industry" is a pivotal initiative addressing the imperative role of research and development (R&D) in steering the country beyond the middle-income trap. Supported by NSRF funds through PMU-B, in collaboration with the private sector and PETROMAT, the platform adopts the "Triple Helix model of innovation." Focused on cultivating top researchers, it emphasizes real-world experience in business scenarios, leveraging BCG Economy and Frontier Technology to address challenges. Aligned with national policy, the project aims to boost the count of R&D personnel to 40 per 10,000 population, strategically advancing Thailand's innovation landscape.

Rationales/Problem statements:

The private sector relies on research and development (R&D) to address company challenges and innovate new products. However, many graduates holding advanced degrees in science and technology lack the necessary qualifications sought by private companies. Consequently, these individuals face barriers to entering the professional workforce. This challenge hampers our national goal to elevate the R&D professionals to 40 per 10,000 population.

Objectives:

1) Establish an innovative platform that cultivates collaboration between post-doctoral and post-master's researchers and the private sector, departing from conventional academia to address industry-specific research challenges.
2) Coordinate Reskill/Upskill/New Skill training programs tailored for seamless integration into the private sector workforce.
3) Foster global collaboration among the education, government, and manufacturing sectors to enhance strategic industry growth.
4) Drive innovation by developing novel technologies, processes, prototypes, and commercially viable products.
5) Facilitate clear career paths for researchers, ensuring professional growth.
6) Actively seek private sector investments in research and development, reinforcing our commitment to pioneering advancements and breakthroughs.

Progress/Findings/Results:

The collaborative research initiative witnessed significant participation, with a total of 40 researchers actively contributing to the project. This dedicated group comprised 24 Postdoctoral researchers and 16 Postgraduate researchers, bringing a diverse range of expertise to the table.

A pivotal aspect of the project's success was the engagement of 23 private companies, playing a crucial role in both financial and in-kind support. The committed contributions amounted to a commendable 6,300,000 baht in cash and an additional 9,900,000 baht in-kind, showcasing the robust backing from the private sector.

The multidimensional nature of the research unfolded across 40 sub-projects, strategically aligned with the New S-Curve Industry. These sub-projects spanned across various domains such as Biofuels & Biochemicals, Bioplastics, Medical Hub, Aviation & Logistics, Digital, Clean Technology, Petrochemicals, Chemicals, High-Performance Materials, Future Food Biotechnology, and Circular Economy. Furthermore, the initiative pushed the boundaries of Frontier Research, driving into cutting-edge areas like Artificial Intelligence (AI), Metaverse, Coding, Frontier BCG, Personalized medicine, Future Food, and Climate Change.

Maintaining a robust communication channel, the project facilitated online meetings to ensure seamless coordination among participating companies and researchers. These sessions served as a platform to address operational updates, discuss challenges encountered in each sub-project, and collaborate on innovative solutions. Additionally, constructive dialogues with executives and private sector research teams took place, paving the way for future research and development partnerships.

In a bid to enhance the skill set of the project participants, two impactful training sessions were organized. The first focused on "Research Impact Evaluation," providing valuable insights into assessing the effectiveness and influence of research outcomes. The second session centered on "Carbon Footprint for Organization Assessment," equipping participants with tools to evaluate and mitigate the environmental impact of organizational activities. These Reskill/Upskill/New Skill training sessions contributed to the holistic development of the research community involved in the project.

Encouragingly, all 40 sub-projects remain on track and are progressing as planned. This steadfast momentum is a testament to the collaborative spirit, dedication, and effective management of the initiative. As the project continues to unfold, the combined efforts of researchers, private companies, and stakeholders promise to yield impactful outcomes, advancing knowledge frontiers and addressing pressing challenges in diverse industry sectors.

Conclusion:

The private sector's endorsement of the platform model stems from its direct and tangible benefits within the project. This favorable reception underscores their willingness to persist in supporting the initiative, marking a harmonious synergy between the project's objectives and the strategic interests of private sector collaborators.

Current Output:

As of the 9-month mark, the project has not yielded tangible results. Nevertheless, anticipated outcomes include 11 publications, 38 prototypes showcasing new technologies and processes, and 9 patents or petty patents. The project's financial performance demonstrates promising returns, with a Net Present Value (NPV) standing at 829 million baht. The Benefit-Cost Ratio (BCR) or Social Return on Investment (SROI) is projected to range from 1.01 to 43.20 times, while the Internal Rate of Return (IRR) is expected to fall within the range of 5.37% to 247.80%. These metrics indicate a favorable outlook for the project's future impact and success.

Challenges/Problems and Possible solutions:

The project encountered challenges stemming from changes in budget disbursement criteria and administrative cuts. PETROMAT's management tackled this by approving the agency's budget and leveraging private sector In-Cash contributions for additional support. Yet, a crucial requirement for a 3-month extension emerged, aligning the initial project timeline with the preparation phase for researchers and the private sector. To ensure an optimal project start, a proposed extension until June 2024 allows ample time for comprehensive preparation and seamless initiation of sub-projects.

Future plan:

The forthcoming plan entails directing private sector participants in the project towards research topics focused on achieving Net Zero Carbon Emission, aligning with the imperative to address environmental sustainability.

Development Program for Frontier Postdoctoral Researchers Through Studies of Photochemical Reactions

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 60%

Abstract:

- Enzymatic decarboxylation of α,β-unsaturated acid using Fdc1 decarboxylase and prFMN cofactor has been of interest because this reaction is an environmentally friendly industrial process for producing styrene. However, experiments showed that isomerization of $prFMN^{iminium}$ to $prFMN^{ketimine}$ is an irreversible light-dependent process, which leads to loss of enzyme activity. Therefore, to improve the decarboxylation process, quantum chemical methods are used to study the photoisomerization mechanism. The theoretical results show two photoisomerization pathways, which involve single and double photoexcitation of prFMN.

- BF_2-formazanates are fluorescent dyes, which could be applicable in photodynamic therapy and microscopy. To improve the efficiency of BF_2-formazanate photosensitizers, quantum chemical methods are used to study the photoluminescent mechanisms. The PES suggested two pathways for $T_1 \rightarrow S_0$ phosphorescence namely, P_1 occurring right after the $S_1 \rightarrow T_1$ ISC, whereas P_2 taking place after the $S_1 \rightarrow T_1$ ISC and T_1 equilibrium structure relaxation. The P_2 phosphorescence are in the near IR range and close to the absorption energy for $^3O_2$ ($^3\sum_g$)$\rightarrow$$^1O_2$ (^1D_g). BF_2-FORM-D is anticipated to be a more effective luminophore than BF_2-FORM, which is due mainly to the heavy atom effect (iodine substitutions).

Rationales/Problem statements:

- **First project:** Because experiments showed that isomerization of $prFMN^{iminium}$ to $prFMN^{ketimine}$ leads to loss of enzyme activity, to improve the enzymatic decarboxylation, photoisomerization mechanism must be studied in detail to find a suitable method to subpress this photoisomerization process.

- **Second project:** Because triplet excited states are difficult to generate through direct photoexcitation and the intersystem crossing (ISC) is symmetrically forbidden, to enhance the triplet excitation, the incorporation of iodine atoms in BF_2-formazanates could help increase the spin-orbit coupling (SOC) and ISC rate, as well as the $^1O_2$ quantum yields of the photosensitizer.

Objectives:

- **First project:** To improve the enzymatic decarboxylation process, quantum chemical methods are used to study the photoisomerization mechanism.

- **Second project:** To improve the efficiency of BF_2-formazanate photosensitizers in photodynamic therapy, quantum chemical methods are used to study the mechanisms of the photoluminescence.

Progress/Findings/Results:

- **First project:** The theoretical results show two photoisomerization pathways, which involve single and double photoexcitation of prFMN.

- **Second project:** Two mechanisms for $T_1 \rightarrow S_0$ phosphorescence are proposed namely, P_1 occurring right after the $S_1 \rightarrow T_1$ ISC, and P_2 taking place after the $S_1 \rightarrow T_1$ ISC and T_1 equilibrium structure relaxation. The P_2 phosphorescence are in the near IR range and close to the absorption energy for $^3O_2$ ($^3\sum_g$)$\rightarrow$$^1O_2$ (^1D_g). BF_2-FORM-D is anticipated to be a more

effective luminophore than BF_2-FORM, which is due mainly to the heavy atom effect (iodine substitutions).

Conclusion:

The DFT, TD-DFT, TST and NVE-MDSH methods are proved to be powerful tools for the investigations of photochemical reaction mechanisms.

Current Output:

Two research manuscripts are being prepared.

Challenges/Problems and Possible solutions:

The proposed photochemical mechanisms could be used as guidelines in future theoretical and experimental studies.

Future plan:

To complete these mechanistic studies, thermodynamic, kinetics and dynamic properties of the proposed photochemical mechanisms will be calculated and included in the analysis.

Nurturing High Potential Researchers Toward Efficient Utilization of Oil Palm Industries to High-value Products

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 60%

Abstract:
This project is a joint effort of three universities, including Walailak University, Taksin University, and Prince Songkhla Nakarin University, to develop a nurturing system of high-potential researchers to work on projects that contribute to advancing the oil palm industries. Four postdocs and two postmaster researchers are working with our industrial partners, Taksin Palm(1978), Bio4gas, and BKE Combustion Controls Co., LTD, in each of their projects to respond to the industries' needs. The nurturing system helps researchers increase their skills and knowledge by offering workshops from local and international experts in the oil palm industry field. The system also involves an individual development plan for each researcher to work with their PI to develop the required skills.

Rationales/Problem statements:
Palm oil is a major industry in Southeast Asia countries and Thailand. Especially in the southern where 70% of Thailand's total 137 crude palm oil (CPO) production factories were located, producing almost 5000 tons of CPO /day. However, prices of CPO, which is only a major product, often fluctuated, resulting directly in the uncertain incomes of oil palm farmers. Therefore, there is a need to develop a new approach to utilizing the oil palm, creating new products through research to maximize the oil palm industry benefits. There are several waste oil palm biomasses, such as oil palm trunks that can be developed into construction materials and furniture or palm empty bunches that can be used as raw material for biochemicals, biohydrogen, and biogas. The utilization of the waste is part of the Bio-Circular-Green Economy, helping push forward the oil palm industries, a First S-Curve, to a New S-curve of biochemicals and biofuels.

Objectives:
1. Develop a nurturing system to develop high potential researcher for the oil palm industries.
2. Cultivate high potential post-doctoral and postmaster researchers able to help advance the oil palm industries.
3. Produce high quality research outputs.
4. Create close cooperation between center of excellence, research units and industrial partner in the oil palm industries.

Progress/Findings/Results:

Activities	Detailed activities
Recruit post-doctoral and postmaster researchers	Four postdoc and two postmaster researchers joined the program
Program Orientation	Online orientation on 18 May 2023, introduction of the oil palm industries and detailing our program to the researchers.
Individual Development Plans (IDPs) between researcher and their PI	Each researcher proposed and developed IDPs with their PI as a tool to reflect the need for skills and to help their work and future career.
Guidance from international experts	On 29 June 2023, Prof.Dr. Yusuf Chisti (h-index 73,) from Universiti Malaysia Terengganu held a workshop on the topic of how to succeed in a research career. On 23 May 2023, Prof.Dr. Samir Khanal (h-index 54) University of Hawaii at Manoa, USA gave guidance and suggestion to the researchers.
Workshops	On 29 June 2023, Mr. Tanongsak Sikaow, vice secretary of Nakorn sri tammarat's provincal industrial broad gave a workshop on the needed research in the oil palm industries. On 29 June 2023, a research seminar in the topics on utilization of oil palm biomass is held in the regional research expo at Walailak University On 27 November 2023, a workshop by Asst.Prof.Dr. Nopporn Thamrongrat on the money planning for the early career, Happy money Happy working place is held.

Conclusion:

Four postdocs and two postmaster researchers joined our program and are working on the research to help pave a new way or solve problems in the oil palm industry.

Current Output: 1 international publication

Challenges/Problems and Possible solutions: None

Future plan:

- Another workshop will be held to improve researchers' skills.
- A research seminar will be held between researchers and industrial partners to accelerate the knowledge transfer.
- Prepare six manuscripts for international publication.

The Rajamangala University of Technology's Postdoctoral and Postgraduate Talent Resource Development to Encourage in Deep Research for improving competitiveness of Industry

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Project duration: 1 year, from 1 April 2023 to 1 April 2024
Current progress: 70%

Abstract:
The research aims to cultivate skilled professionals and researchers for smart food and agriculture transformation, high-value creative industries, digital education, and technology and innovation manufacturing. To enhance competitiveness in the enterprise sector, deep research and appropriate technology are crucial. Leveraging the potential and resources of researchers at Rajamangala University of Technology (RMUT), industry needs were identified and matched with suitable technologies and researchers. Post-master and post-doctoral researchers, supervised by RMUT experts, collaborated with industry partners to address specific challenges. The outcomes include not only lab-scale results but also prototype products, problem-solving, and publications. Examples include a lightweight composite EV car and fine bubble generation for the cosmetic industry. The development of human capital through deep-tech talent will further boost Thailand's industrial competitiveness.

Rationales/Problem statements:
To transfrom conventional agriculture, manufacturing, and service sectors to high value agriculture, high-value creative industries, and technology and innovation manufacturing, the potential and resources of manpower is an important key parameter. Food industry, education industry, future mobility and green technology plays major role in Thailand. The compettitiveness of industrial sector can be increase by using technology and innovation. For sustainable development, research and innovation by Thai talent manpower is required. The developing human capability in knowledge, skills, and industry soft skill can be done under expert talent shadow. Scounting, matching and suiatable research and researcher will answer and co-develop with technology user. The goal is to bring knowledge and technology from expert and apply them to the development industries in Thailand. This approach will increse industrial efficiency through deep research.

Objectives:
-To develop a post-doctoral and post-master's research promotion system within the group of Rajamangala University of Technology
- To enhance deep research capabilities
- To elevate the competitiveness of industries in Thailand.

Progress/Findings/Results:
This research work is focused in agriculture and food industry, education industry, future mobility and green technology industry. 14 post-mater and 6 post doctoral researchers conducted the research incollabolation with 15 industries. The suiatble research and

innovation was conducted to produced model material, prototyping and problem solving innovation. For agriculture and food industry, the agriculture waterwaste treatment catalyst and nanobubble treatment system was investigated. For education industry, robotic and automation learning platform and education technology was produced. For future mobility, ligth weigth composite for conversion EV car, drive motor for EV car, control electronic system for EV car and model for railway operation was studied. For green technology industry, fabric softener from cellulose, PM2.5 monitoring system, mosquito repellent from bio-based polymer, heat protection color from cellulose was invented in this researh work.

Conclusion:

The competitiveness of industry was increased by apply the research and innovation. Post-master and post-doctoral research have conducted the research from problem setting and solving in collaboration with industry. Prototypes, products, and processes wer investigated in this work.

Current Output:

8 publication in Scopus, 14 Prototypes and products

Challenges/Problems and Possible solutions:

The application in real sector and for mass scale production is challenges.

Future plan:

- Publication
- Product and prototype testing

Sharing R&D Unit System for Thai Industrial Value Chain

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Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 25%

Abstract:

Science and Technology is the main key to drive Growth & Competitiveness of Thailand. Innovation driven enterprise could be established based on R&D activities. Technology gap and insufficient researchers in the majority of private section, i.e. SMEs, are the main challenges. The development of Ecosystem that could close the technology gap and resolve human resource issues has been focused in this project.

Collaborations between research and education organization and private sector through value/supply chain could be a potential solution for SMEs strengthening. In this project, a concept of Sharing R&D Unit System has been purposed. The concept is to connect company with different scale and market position using research project. Industrial oriented researcher development is the main driving element of the project. Not only research findings and phototype development based on industrial demand but also technology transfer, experience exchange and R&D skill and attitude adjustment are considered.

Rationales/Problem statements:

Sustainable development require integration of talents and basic knowledge corresponding to national policy and global trend leading to innovation that could fulfill industrial demand. Translational phase between basic research and commercial product depends strongly on translation research/researcher to close the gap within value/supply chain. To develop innovation or strengthening competitiveness, different company face different challenges/problems depending on company positioning in value/supply chain and financial status. To understand company situation and position and define problem statement to be solved with R&D for company competitiveness strengthening is the key to success. This project aims to develop the ecosystem framework with industrial oriented researcher as the main research tool which could provide **Sharing R&D Platform for Thai Industrial Value Chain.**

Objectives:

1. To promote R&D investment in Private sector
2. To promote and strengthening R&D and Innovation skill in SMEs
3. To develop ecosystem for sustainable Sharing R&D Unit for Thai Industrial Value Chain

Progress/Findings/Results:

The initiative phase of the project focus on research field that related to the majority of industries in Thailand which are materials and surface engineering and manufacturing process. The aim of the project is to enhance core value, standard and competitiveness of the company to match requirements for new/higher value market/industry**.**

The project methodology are given below

1. Review research results and finding (TRL 3-4) and industrial demand and requirements and develope industrial based research concept.
2. Identify potential linkage and networking for target industry based on final user (Top of value/supply chain)

3. Perform Co-Research&Development project that satisfy requirements and market opportunities

The following findings were found for different group of company.

MNCs and Large face Human Resources & Development and Skillful Supply chain problem;

- insufficient skillful industrial based researcher and engineer,
- lack of appropriate Human Development platform,
- supply chain reliability.

SMEs deal with Innovation understanding, R&D infrastructures, market opportunities and R&D readiness development challenges;

- financial problem,
- lack of expert, researcher and engineer,
- attitude towards R&D and government policy and agents issue,
- access or limitation to market and support.

At present, five initiative co-research and development projects have been developed. Each composes of 2 major components; 1. Experienced senior consultants and junior industrial oriented researchers with appropriate basic knowledge and research experience corresponding to industrial partner demand and potential innovation. 2. industrial partners ranging from upstream to downstream in value chain.

Conclusion:

The framework to upgrade the competitiveness of private sector especially SMEs targeting on R&D workforce has been developed. The material/surface engineering and manufacturing process has been focused at this early stage. The framework starts with defining the project concept based on industrial partner situation and market positioning. The basic research results with TRL4 has been applied to solve technology problem or complete commercial demand. The research project scope and plan has later developed utilizing R&D skill and science and technology knowledge. Five initiative projects have been initiated leading to development of company networking together with research finding and prototype.

Current Output:

5 Industrial based projects with 5 industrial based researchers

2 Postmaster

1. Development of Thermal-Based NDT Technique to Detect Defect Areas
2. Lifetime Improvement of Capillary used in Laser Solder Ball Jetting Process

3 Postdoc

1. Rheological analysis for single-use package manufacturing from thermoplastic starch
2. Development of Smart Coatings — Wear and Corrosion Based Photo Luminescent Sensing for Elevated Temperature Applications
3. Development of Coating using Low-Pressure Spray Machine

5 Key industrial partners

1. ACME INTERNATIONAL (THAILAND) LTD.
2. SEAGATE TECHNOLOGY (THAILAND) COMPANY LIMITED with NICHIDAI (THAILAND) COMPANY LIMITED collaboration
3. SIAM MODIFIED STARCH COMPANY LIMITED
4. MECHANIC ENGINEERING SERVICE COMPANY LIMITED
5. BLUE MANAGEMENT SERVICE COMPANY LIMITED

Challenges/Problems and Possible solutions:

Possible Challenges

Change in industrial partner requirement and roadmap due to updated situation, i.e. requirement, available budget, equipment's availability.

Potential Solutions

1. Trying to adjust the scope and methodology according to the user requirements but fulfill research requirement.
2. Working closely with industrial partner and searching for collaborations if required to solve the problems.

Future plan:

Current phase

1. Co-Research and Development with industrial partner to obtain
   5 Q1 research publication and 5 Prototype (TRL >4)
2. Expand the project to create innovation driven community with CRDC provide sharing R&D Unit with ecosystem to support and link the stakeholders in the supply and value chain for target product.

Next step

1. Expanding research field
2. Expanding linkage to international market or higher value market
3. Capacity building and Sustainability Model

Development of Frontier Researchers in Nanomaterials for Supporting Industrial Research Problems

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Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 30%

Abstract:

This project aims to develop frontier research in nanomaterials to support industrial research problems. The project is divided into 6 sub-projects, as follows:

1. Improving the performance of thermoelectric materials by adding acetylene black nanocomposites
2. Enhancing Electrical and Mechanical Properties of Acetylene Carbon Black/Cement Paste Composites
3. Development of carbon dioxide carriers by nanobubble techniques for enhancing economic plant growth
4. Development of Natural Rubber Nanocomposites as an Air Filter for CO_2 Capture and Energy Harvesting
5. Green Porous Carbon Derived from Sawdust Activated by a Seawater Activator for a Supercapacitor Application
6. Synthesizing Calcium Carbonate ($CaCO_3$) Material from Natural Waste Materials Using Carbon Dioxide Adsorption for Applications in Capacitors and Humidity-Sensing Devices

Six postdoctoral researchers are working on each project. Since the project has only started for 3.5 months, the outputs (publications, patents, and prototypes) have not been readily successful yet. However, the progress is according to the research plan, and the outputs are expected within the timeline of the project.

Rationales/Problem statements:

This project was developed from the research problems we received from industrial/commercial sectors. The company involves in this project are

1. IRPC Public Company Limited : Project 1&2.
2. Medical Facility Management Co., Ltd. : Project 3.
3. Renew Innovations Co., Ltd.: Project 4.
4. Mitr Phol Sugar Co., Ltd.: Project 5&6.

The industrial sectors mainly want to develop new products, improve their existing products, or utilizing wastes from their routine production. For example, IRPC is keen to explore the potential of their products, acetylene carbon black. Medical Facility Management is interested in nanobubble techniques for various applications. Renew Innovations wants to

improve natural rubber for using as an air filter for CO_2 capture and energy harvesting. Mitr Phol Sugar hope to exploit natural waste materials for value-added products.
As we received these research problems, we developed this project to serve their need. The success of the project will benefit both academic and industrial sectors in Thailand.

Objectives:

To develop frontier research in nanomaterials for supporting industrial research problems.

Progress/Findings/Results:

Project 1:

Explored conditions for dispersing acetylene carbon black (ACB) in Ethylene Glycol/DI water to create a composite with Ag2Se. The composite powders, containing varying ACB percentages, were consolidated by warm-pressing. While XRD revealed the pure phase of orthorhombic Ag2Se, SEM images confirmed ACB presence in the structure. Thermoelectric properties, including electrical conductivity, Seebeck coefficient, and thermal conductivity, were measured. The 5.0 wt.% ACB sample emerged as the optimized configuration, exhibiting a zT of 0.75 at 380 K.

Project 2:

Investigated optimal conditions for incorporating acetylene carbon black (ACB) into cement paste. Utilized 0.2% weight of HEC and 0.05-0.4% weight of SP to achieve a smooth flow and easy casting. The addition of ACB led to a decrease in electrical resistivity due to its low resistance, enhancing the electrical conductivity of the cement paste. Initial strength decline observed at 7 and 14 days was attributed to reduced binder, but no discernible impact on strength was observed after 28 days, indicating effective integration of ACB within the microstructure.

Project 3:

Generated CO2 nanobubbles (NBs) using a decompression method and stabilized them with Span 60 (SP60) and a combination of Span 60/Tween 20 (TW20). Examined 13 samples with varying surfactant ratios and content. Selected stable samples for a plant growth test with rice (Oryza sativa) variety Kor Khon79. Sowed seeds, transplanted seedlings, and prepared for a one-month plant growth test using chosen samples.

Project 4:

Investigated the potential of NR-foam filters for dual applications in air purification and CO2 capture. The foaming process increased porosity and surface roughness, improving air filtration efficiency. Activated carbon addition ensured uniform distribution, significantly enhancing CO2 adsorption performance. NR-foam filters generated a remarkable electrical output of approximately 90 V, making them cost-effective energy sources for CO2 capture. Suggested further optimization using a triboelectric nanogenerator for maximizing filtration performance.

Project 5: Successfully produced activated carbon (AC) from sawdust using either a NaCl or seawater activator. X-ray diffraction (XRD) identified pure amorphous carbon structures, particularly in the AC-0.6 M NaCl-900 sample with the highest adsorption quantity. All activated carbons exhibited pure amorphous carbon structures. Sawdust treated with a seawater activator at 900°C (AC-seawater-900) and AC-0.6 M NaCl-900 demonstrated higher adsorption quantities than the non-activated one (non-AC-900), indicating larger specific surface areas. Specific capacitance of AC-seawater-900 and AC-0.6 M NaCl-900 electrodes was higher than that of the non-AC-900 electrode, likely due to their larger specific surface area.

Project 6:

Synthesized Calcium Copper Titanate (CCTO) from waste shells through carbon dioxide adsorption. Utilized resulting material to prepare CCTO via a solid-state reaction with copper

oxide and titanium dioxide. Optimized reaction parameters, including temperature and duration, for enhanced phase purity and crystalline structure. CCTO exhibited promising potential in high-energy storage capacitors and humidity change sensing devices. Adjusting fabrication process parameters could further enhance the dielectric constant, allowing for customization of material properties for specific applications.

Conclusion:

After 3.5 month from the beginning of the project, we have carrier out the research according to plan. The results are satisfactory. Although the outputs are not ready at the moment, they are expected to be produced within the timeline of the project. The current progress is around 30%.

Current Output: -

Challenges/Problems and Possible solutions: -

Future plan:

Further research and experiments according to the research plans.

Human Resource Development in Zinc Oxide Nanoparticles Synthesis Using Green Chemistry to Fulfill the Needs of the Cosmetics Industry

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Project duration: 1 year, from 1 August 2023 to 31 July 2024

Current progress: 40%

Abstract: The synthesis of plant-based nanoparticles has many benefits over traditional physico-chemical techniques and has diverse applications in cosmetic. In the current study, green tea (GT), *Camellia sinensis*, was used to make Zinc oxide nanoparticles (ZnO NPs) for cosmetics industry. The nano-sized personal care products formulations have tendency to either speed up or retard the absorption of ingredients into the skin albeit to a minimal scale. ZnO NPs with excellent UV filters are present in latest sunscreens/sunblocks, and these nano constituents do not penetrate human skin. It passes the safety parameters through tests/analysis of cytotoxicity, toxicity, and carcinogenicity studies. This study towards weighted benefits of UV-induced skin aging and cancer compared to vague concerns. It would open gamut of applications of ZnO NPs in the field of cosmetics. Given the growing commercial and scientific interest, this chapter will highlight the effectiveness, safety, and toxicity of ZnO nanoparticles in cosmetics industry.

Rationales/Problem statements: The evidences of the harmful effects of skin exposure to excessive UltraViolet (UV) radiation, primarily on the development of skin cancer, have increased over the last decade. Thus, researchers have encouraged the public to take protective sunscreens, and respectively also everyday cosmetics containing UV filters. Zinc oxide (ZnO), a mineral called zincite, is found in the earth's crust. ZnO makes a suitable addition for fabrics and surfaces that come into touch with a body that is harmless and gentle on human skin. ZnO NPs have been extensively utilized for multiple purposes because of their low level of toxicity and size reliant characteristics. ZnO NPs have greater promise to cure infectious disorders in people and animals since ZnO NPs is generally regarded as harmless and possesses antibacterial characteristics. Due to its unusual physical and chemical characteristics, ZnO NPs, one of the most significant metal oxide nanoparticles, are often used in a variety of sectors. These benefits allow ZnO NPs to be chosen as promising nanoplatforms for cosmetics application.

Objectives: The aim of the research was to employ two related parts of the production of zinc oxide nanoparticles (ZnO NPs) analogs through the preparation of catechin extract from green tea (*Camellia sinensis*) as form of reducing agent and stabilizing agent for one-pot template synthesis of ZnO NPs. The nanostructure formation of ZnO NPs in the presence of template were investigated using UV-Vis, Zetasizer and TEM. The cytotoxicity of the NPs was also examined. Our finding is one of a promising and pragmatic technique to prepare targeted ZnO NPs as a substrate for cosmetics industry.

Progress/Findings/Results: In the current study, green tea (GT), *Camellia sinensis*, was used to make ZnO NPs for functional testing in cell line. Gamma irradiation was carried out using a ^{60}Co source from Gamma Cell 220 irradiator with an absorbed dose rate of 8.6 kGy/h. To determine chemical structure of functional ZnO NPs formation, Fourier transform

infrared spectrometry was performed. The structural and optical properties of NPs were examined by Fourier transform infrared (FTIR) spectroscopy, transmission electron microscope (TEM), ultraviolet-visible spectrophotometer (UV-Vis) and dynamic light scattering (DLS). Hydrodynamic diameters and zeta (ζ) potentials were measured. GT powder was irradiated with gamma-rays at various doses. Total phenols content and the antioxidant effect of green tea extract on 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radicals was measured. After the synthesis of ZnO NPs, this experiment was performed using ranges of Zno NPs concentrations. The most apparent alterations in FTIR spectrums, among others, were in the region of 3,600-3,200 cm^{-1}. The GT-0 (~340 nm) is varied in hydrodynamic size and the population particle size with higher content in GT-0 (~230 nm). The zeta potentials of GT-10 were measured in the range of -20 to -30 mV signifying incipient stability. TEM images of GT without irradiation are of various sizes of spherical shape and the GT irradiated at 10 kGy has a similar size of spherical shape around 200-400 nm. The phenolic content in GT without irradiation was 80.19 mg/g and increased to 86.36 mg/g after irradiation at 10 kGy. No significant difference was found between the phenolic content of GT irradiated after 10 and 20 kGy of doses. 10 kGy of gamma ray showed the highest antioxidant capacity and a complete reaction occurred at 0.3 mg/mL GT. The green synthesis of ZnO NPs revealed cytotoxicity effects in cosmetics application. Our studies provide compelling report that ZnO NPs could be a potential nano ingredient approach for cosmetics and it can be further enhanced the therapeutic efficacy and minimize side effects of cosmetics agent.

Conclusion: This study performs the successful production of zinc oxide nanoparticles (ZnO NPs) analogs through the preparation of catechin extract from green tea (*Camellia sinensis*) as form of reducing agent and stabilizing agent for one-pot template synthesis of ZnO NPs. The green synthesis of ZnO NPs revealed cytotoxicity effects in cosmetics application. Our finding is one of a promising and pragmatic technique to prepare targeted ZnO NPs as a agent for cosmetic fields, which will be helpful for facilitating their future research progress and focusing on biomedical fields.

Current Output: 1 Publication

Challenges/Problems and Possible solutions: -

Future plan: ZnO NPs have exhibited promising biomedical applications based on its anticancer, antibacterial, antidiabetic, anti-inflammatory, drug delivery, as well as bioimaging activity. We believe that these nanomaterials would dramatically promote the development of medicine, and ZnO NPs are expected to make more exciting contributions in these fields.

Manpower Development in Electrochemical Sensors and Biosensors

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Project duration: 1 year, 1 August 2023 to 31 July 2024

Current progress: 40%

Abstract:

The proposed research project will include four sub-projects for manpower development in electrochemical sensors and biosensors. These sub-projects are as follows: Sub-project 1: Development of electrochemical sensors for the detection of capsaicin, Sub-project 2: Design of a biosensor for detecting the ratio of albumin to creatinine in samples, Sub-project 3: Development of electrochemical sensors for detecting curcumin in turmeric, and Sub-project 4: Development of electrochemical sensors for detecting mercury in cosmetics. All four sub-projects are focused on developing scientific expertise and producing highly skilled innovators. They have mechanisms in place to cultivate research personnel through these sub-project research challenges. The expected output from this project is as follows: 1.) it will generate two post-doctoral and two post-master, 2.) it will publish four international papers, 3.) it will generate at least two product prototypes, and 4.) it will submit at least two patents or petty patents.

Rationales/Problem statements: None

Objectives:

1. To produce and develop research personnel in order to improve manpower in the fields of electrochemical sensors and biosensors, as well as to create highly skilled innovators to meet the needs of the country.
2. To publish knowledge gained from the development of electrochemical sensors and biosensors in international journals.
3. To apply for patent or petty patents within the country.
4. To create prototypes for the industry.

Progress/Findings/Results:

The findings of these sub-projects are as follows:

Sub-project 1: A laser-induced graphene disposable electrode made from biomass was successfully developed using a simple and facile fabrication method involving laser irradiation. This electrode exhibits good electrochemical properties and has been successfully applied to the determination of capsaicin.

Sub-project 2: Activated carbon was successfully synthesized from palm kernel shell using the pyrolysis method. The use of ball mill technology results in a reduction in the gain size of AC-PKS (activated carbon-palm kernel shell) material to nanoscale, as well as an increase in oxygen functional groups on the surface of AC-PKS. During the ball mill process, the dispersion in organic solvent went through an increase. The presence of oxygen functional

groups on the PKS surface facilitates the absorption of methylene blue, which can act as a redox probe for further label-free albumin biosensor.

Sub-project 3: A portable curcumin (CUR) sensor based on a nitrogen and sulfur-doped laser-induced graphene electrode was successfully developed. The proposed method provided a wide linear range, low detection limit, excellent reproducibility, and good repeatability. Moreover, this sensor could possibly be applied for the determination of CUR in cultivated rhizomes and commercial turmeric products.

Sub-project 4: Mercury is a toxic metal that can cause severe toxic effects, including kidney damage, anxiety, depression, and peripheral neuropathy. In this study, $Bi(NO_3)_3/MoS_2$ nanocomposite was used as a working electrode for the development of an electrochemical sensor for the detection of mercury (II) ions. The study also involved optimizing the analyte and operating conditions, aiming to improve the selectivity, sensitivity, and reliability of the electrode for mercury detection.

Conclusion:

The following are the conclusions of these sub-projects:

Sub-project 1: A biomass-induced graphene disposable electrode developed through laser irradiation was successfully used for the determination of capsaicin due to its excellent electrochemical properties.

Sub-project 2: Pyrolysis and ball mill technology were used to create activated carbon from palm kernel shell, reducing gain size to the nanoscale and increasing oxygen functional groups. This improved dispersion in organic solvents, potentially facilitating methylene blue absorption in label-free albumin biosensors.

Sub-project 3: A portable curcumin sensor developed with a nitrogen and sulfur-doped laser-induced graphene electrode has a wide linear range, a low detection limit, excellent reproducibility, and potential applications in cultivated rhizomes and commercial turmeric products.

Sub-project 4: The study used a $Bi(NO_3)_3/MoS_2$ nanocomposite to develop an electrochemical sensor for mercury detection, with the goal of improving selectivity, sensitivity, and reliability by optimizing the analyte and operating conditions.

Current Output: The publication/patent/prototype will be obtained within one year (2024)

Challenges/Problems and Possible solutions: None

Future plan:

1. Study the efficiency of the developed analysis method.
2. Prepare the original research manuscript for publication in international journals.
3. Design and create a prototype product.
4. Prepare the intellectual property submission documentation.

Development of a New System for the Transcriptional Regulation of Lipid Accumulation in Yeast and Analysis of Protein Interactions in Lipid-Accumulating Pathways Using Omics Technologies

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Project duration: 2 years, from 1 October 2021 to 31 October 2023

Current progress: ~75%

Abstract: *Yarrowia lipolytica* is an oleaginous yeast producing triacylglycerol (TAG) for biofuel application. The purpose of this study was to create a transcriptionally controlling system for TAG accumulation in *Y. lipolytica* via a conditional gene repression using glycerol. First, a modified *Y. lipolytica* (ESIG) strain consisting a glycerol-repressed EYK1 promotor-joined SNF1 gene cassette was successfully constructed and confirmed by PCR and growth analysis. Next, the expressions of *YlSNF1* gene and protein under a glycerol-dependent regulation in ESIG were demonstrated. Furthermore, ESIG displayed higher lipid staining fluorescence intensity by Nile red compared with WT when induced by glycerol at 24 h. The fatty acid composition analysis revealed non- different fatty acids, compared with WT. Also, transcriptome analysis of ESIG compared to WT disclosed 356 differentially expressed genes (DEGs) ($|\log2FC| > 1.5$), in which downregulated DEGs were mainly associated with the downregulation of fatty acid degradation. Phospho- and pull-down proteomes are currently undergoing.

Rationales/Problem statements:

Biodiesel is an alternative source of energy that is considered as one of renewable resources, making it a promising way to replace fossil fuel. At present, several plants are employed as sources of biodiesel production. However, plant biodiesel encounters several hurdles including uncontrolled growing conditions, price variation, and uncontrollable fatty acid compositions. Thus, oleaginous microorganisms are another promising source of biodiesel. *Yarrowia lipolytica* is an oleaginous yeast that can efficiently accumulate triglyceride in the cell, making it an excellent organism to produce and accumulate fats. A previous study demonstrated that the mutation of *YlSNF1* could enhance the lipid accumulation in *Y. lipolytica.* Though, the deletion of *YlSNF1* could lead to a severely growth defect. Thus, an engineered strain of *Y. lipolytic* that allow a normal proliferation phase and switch to lipid accumulation phase is required to established efficient an oleaginous yeast strain with high lipid production for biodiesel application.

Objectives:

1. To create a novel conditional gene repression system to regulate the TAG accumulation in *Y. lipolytica*.
2. To investigate the transcriptome and identify associated lipid accumulation-controlling pathways.
3. To construct an interaction network of proteins that are involved in the lipid accumulation in *Y. lipolytica* using phosphor-and pull-down proteomics.

Progress/Findings/Results:

First, a modified strain of *Y. lipolytica*, so-called ESIG, in which the *YlSNF1* gene cassette was joined to a glycerol-repressed EYK1 promotor was successfully constructed by a pop-in method. The newly constructed ESIG was confirmed by PCR technique. Its function was examined by a growth analysis. According to the result, the growth of ESIG was similar to the wild-type strain while the Δ*Ylsnf1* strain that was an original strain used to create ESIG exhibited a severe growth defect on different media containing glycerol, glucose, and

erythritol. Furthermore, *YlSNF1* was expressed in response to the glycerol induction which was confirmed by the expressions of *YlSNF1* gene and protein. The expression of *YlSNF1* dramatically decreased at 1- and 3-hour glycerol and glucose induction. Likewise, the protein expressions of YlSnf1 at 6- and 12- hour were lowered in the glycerol and glucose induction. and Next, the lipid accumulation was evaluated by Nile Red staining. The results showed that ESIG accumulated more lipids than CXAU/AI wild-type at both 6 and 24 hours. The fatty acid compositions in ESIG were similar to CXAU/AI wild-type, mainly including stearic acid, Erucic acid, palmitic acid, and oleic acid. The transcriptome analysis and enrichment analysis of ESIG induced by glycerol compared to that induced by erythritol demonstrated that genes involving the fatty acid oxidation and degradation were downregulated and genes involving the fatty acid synthesis and amino acid biosynthesis were upregulated. In summary, the newly gene repressor system for *YlSNF1* was established in *Y. lipolytica* with enhanced lipid accumulation, compared with wild-type CXAU/AI. The increased lipid accumulation of ESIG was through the upregulation of enzymes associated with fatty acid synthesis, together with the downregulation of the fatty acid oxidation.

Conclusion:

The newly modified strain of *Y. lipolytica*, ESIG, with a YlSNF1 gene repression system was successfully constructed by using a pop-in method. The *YlSNF1* repression system was validated by qPCR and western blotting technique. The transcriptome analysis revealed that the glycerol inducing gene repression of ESIG led to both significant downregulation of genes involving fatty acid oxidation and upregulation of genes in fatty acid biosynthesis processes. ESIG substantially accumulated more lipids than the wild-type when the cells were induced by glycerol.

Current Output:

: Currently one manuscript entitled "*SNF1* is Crucial for n-alkane Utilization in the Yeast *Yarrowia lipolytica*" is under a review process (submitted to Biochemical and Biophysical Research Communications (BBRC)).

2. Petty Patent: Proposed 1 patent

: Currently in preparation on the process of making engineered Yarrowia lipolytica.

3. Researchers/ Graduates: Proposed 2 scholars

: One MS graduate with specialized scientific skills in gene engineering, yeast cultivation, and lipid accumulation analysis

: Currently, one assistant researcher working on the project.

Challenges/Problems and Possible solutions:

Delay of the project was due to the optimization of the culture condition for high lipid production of ESIG. Delay of the phosphoproteomics was due to the low quantity of proteins for proteomics.

Future plan:

The culture condition for ESIG to accumulate high lipid content is ongoing. Next, a phosphoproteomics and pull-down proteomics of ESIG induced by glycerol will be performed to construct a protein interaction network that is associated with lipid accumulation in *Y. lipolytica*.

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ด้านการพัฒนากำลังคนทักษะสูง (Industrial/Frontier Postdoc) พลังงานหมุนเวียน วัสดุขั้นสูง ดิจิทัลและปัญญาประดิษฐ์

Development of High Performance Post-Doctoral Researchers for Frontier Catalysis Research via a Combined Technique in Experiments, Quantum Chemistry, and Artificial Intelligence to Support Green Chemicals and Clean Energy Production and Achieve Net Zero Emissions

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 50%

Abstract:
This project aims to develop the high performance post-doctoral researchers for frontier catalysis research via a combined technique in experiments, quantum chemistry, and artificial intelligence to support green chemicals and clean energy production and achieve net zero emissions. In the first group, we focused on the catalytic ethanol conversion, which we can transform ethanol into more valuable chemicals such as ethylene, acetaldehyde and ester using proper catalytic materials. In the second group, the catalytic researches up on photocatalysis and electrocatalysis were conducted. The synthesis of TiO_2 nanoparticles-based materials for photocatalytic applications such as for waste water treatment was investigated. In addition, the synthesis of transition metal electrocatalysis for hydrogen evolution reaction was also performed. In the third group, the catalytic research based on using the quantum chemistry was investigated using density functional theory (DFT) and high entropy alloy (HEA).

Rationales/Problem statements:
To upgrade the frontier research quality in Thailand, it is more crucial to develop the high performance post-doctoral researchers for frontier research, especially on catalysis research area. At present, the world focuses on the sustainable development goals (SDGs) announced by the United Nation. Issues such as carbon neutrality, net zero emission, green chemicals and clean energy production are emphasized. To achieve the goals, catalysts play important roles in the production processes. Design of suitable catalysts can alter the production conditions, the product distribution, and the durability or reusability. These will lead to less carbon emission, cleaner technology (less energy usage and less impurity in product), etc. Therefore, the design of suitable catalysts is important. This project aims to first, develop the high performance post-doctoral researchers for frontier research including catalytic ethanol conversion, photocatalysis & electrocatalysis, and quantum chemistry.

Objectives:
This project aims to develop the high performance post-doctoral researchers for frontier catalysis research via a combined technique in experiments, quantum chemistry, and artificial intelligence to support green chemicals and clean energy production and achieve net zero emissions. The publication in Q1 and Tier 1 journals is also the main goal of this project.

Progress/Findings/Results:
The overall project is in progress. Everything is on plan. The post-doctoral researchers have performed well. All of them have submitted the manuscripts based on their research area including in catalytic ethanol conversion, photocatalysis & electrocatalysis, and quantum chemistry. It is believed that all significant finding up on the mentioned research area will be found acceptable. In fact, two of them have already published in Tier 1 journals including Advanced Theory and Simulations and Chemosphere.

Conclusion:
The investigation of this project is in progress as planned. Significant findings up on the proposed research areas were achieved and have merit publication in the high-quality journal. We already have two research paper published in Tier 1 (top 10%) journal. The rest of them is under review.

Current Output:
Two Tier 1 (Top 10%) papers

1. Rittiruam *et al.*, *Adv. Theory Simul.* **2023**, 2300327
2. Saelee *et al*., *Chemosphere*, **2023**, 139842

Challenges/Problems and Possible solutions:
Tier 1 & Q1 take long time and difficult. Try to find new journals.

Future plan:
Revise the manuscripts up on the reviewers' comments.

Consortium for Nurturing Talent Pioneers in Materials Science and Technology to Drive Thailand to BCG Economy

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 50%

Abstract:
To propel Thailand towards Innovation-Driven Enterprises (IDEs), it is important to create a sustainable research ecosystem. This approach aims to foster domestic innovation, reducing dependence on foreign technology. Among the key technologies, Materials Science and Technology stand out, playing a crucial role in driving innovations that align with the BCG economy policy. "Consortium for Nurturing Talent Pioneers in Materials Science and Technology to Drive Thailand to BCG Economy," seeks to address this imperative. It places a strategic focus on cultivating talent in four key areas: (1) Smart Biomaterials, (2) Smart Sensing Materials, (3) Emerging Energy Materials, and (4) Environmentally Benign Catalysts/Cement Materials. These areas have been identified as critical demands from industry.
This project entails a collaborative effort involving three universities and five companies. The aim is to nurture 13 postdoctoral and postgraduate researchers who will contribute to publications in Q1 journals and prototypes tailored to meet the needs of collaborating industries.

Rationales/Problem statements:
Thailand's competitiveness has faced a decline attributed to higher wage costs and a prevalence of low-skilled workforces. The industry is now experiencing a pronounced need for highly skilled professionals capable of leading research and development initiatives, thereby aiding companies in the creation of high-value products. An important area to elevate the skill set of the workforce towards Innovation-Driven Enterprises (IDEs), is materials science and technology.
"Consortium for Nurturing Talent Pioneers in Materials Science and Technology to Drive Thailand to BCG Economy" is designed to cultivate talents in four themes: (1) Smart Biomaterials, (2) Smart Sensing Materials, (3) Emerging Energy Materials, and (4) Environmentally Benign Catalysts/Cement Materials. The primary objective is to meet the industry's demand for skilled professionals in these specialized areas, contributing to the enhancement of Thailand's competitiveness in science and technology. Through this consortium, we aim to align with the BCG economy model, positioning Thailand as a leader in the global economy.

Objectives:
1) To produce and develop manpower in the advanced higher education system in materials science and technology that is internationally competitive.
2) Nurturing expertise in materials science and technology to drive innovation in a sustainable, eco-friendly economy. Emphasis is placed on fostering highly skilled professionals, with opportunities for research collaboration in industry. This involves addressing research queries originating from the industrial sector, particularly focusing on cutting-edge research topics outlined in the sub-project proposal.

3) To create a global research and development network in materials science and technology.
4) To promote and develop the research and innovation ecosystem in materials science and technology.

Progress/Findings/Results:

The progress from 4 different research themes can be listed as follows:

(1) Research in smart biomaterials is dedicated to utilizing agricultural resources for the development of biomaterials, both for medical applications and those derived from agricultural raw materials. Medical applications involve comprehensive testing of material performance at cellular, tissue, and animal levels, adhering to relevant standards and conditions. Collaborating with IRPC Public Company Limited and Nova Medic Company Limited, the private sector provides crucial support through tools for enhancing production, including those for molding medical devices. The project's industrial sectors contribute to scaling up experiments, leading to product prototypes and innovations. IRPC Public Company Limited also plays a role in supporting post-doctoral and post-master's scholarships.

(2) Smart sensor materials research prioritizes the development of human resources and industry in the realm of health-focused smart sensor materials, such as biosensor test kits for detecting specific cancer markers. The collaboration with Serf Science Company Limited involves the fabrication of nanomaterials for sensor components and the assembly of biosensor devices based on basic electrodes developed by the company. Working with the private sector, the research involves scaling up production and testing the properties obtained from large-scale production. This process aims to optimize biosensor fabrication for quick mass production using existing production tools and resources. Additionally, there are collaborations with Nano Generation Company Limited to develop a stable humidity sensor and create a dust measuring device with high accuracy.

(3) The research in emerging energy materials seeks to expand cooperation with the industrial sector by developing a new type of anode material—specifically, a composite material of Si/SiO_2, Sn/SnO_2, or TiO_2 on a graphene material support containing a network of conductive polymers. This material is intended for use as an anode in lithium-ion batteries, focusing on high energy density, light weight, safety, long service life, fast charging technology, and low production costs. The project involves transferring skills and using tools in battery cell assembly and production. Collaborating with Advanced Surface Technology Company Limited, the research supports post-master's/doctoral level researchers and production factors/technology to develop a metal-air battery system—an alternative battery technology with a less complex system that utilizes an electrochemical reaction using a metal alloy anode.

(4) Research on environmentally benign catalysts/cement materials involves collaboration with SCG Cement Company Limited to develop catalysts alongside construction materials, introducing diverse functionalities to enhance the value of construction materials. The integration of environmentally friendly materials is facilitated by private companies participating in the project, which contribute to research ideas and to both technical and consumer demand dimensions. Joint development efforts include a new type of photocatalyst material utilizing solar energy for activation, aimed at removing hazardous organic and inorganic substances that are challenging to decompose and often persist in the environment. This innovative material can replace traditional catalysts in processes involving organic substances, reducing toxicity and chemical residue.

Conclusion:

The project fosters 13 postdoctoral and postgraduate researchers with mentors from 3 Thai universities, together with demands from 5 companies in 4 different areas: (1) Smart Biomaterials, (2) Smart Sensing Materials, (3) Emerging Energy Materials, and (4) Environmentally Benign Catalysts/Cement Materials. The progress outputs from the projects are 2 papers (1 published and 1 under review), creating a mechanism for cultivating research personnel through research networks with 5 partner industries.

Current Output:

1. N. Tuancharoensri, S. Sonjan, S. Promkrainit, J. Daengmankhong, P. Phimnuan, S. Mahasaranon, J. Jongjitwimol, P. Charoensit, G. M. Ross, C. Viennet, J. Viyoch,* S. Ross*, Porous PolyZ2 **-** hydroxyetyl methacrylate) Hydrogel Scaffolds for Tissue Engineering: Influence of Crosslinking Systems and Silk Sericin Concentration on Scaffold Properties, Polymers 2023, 15(20), 4052; IF (2022) = 5.0, Q1

2. S. Shuecamlue, A. Taman, P. Khamnantha, C. Banjongprasert* Microstructures, Mechanical Properties, and Corrosion Behavior of Flame-Remelted Thermally Sprayed NiCrBSi/WC-Co Coatings, Surfaces and Interfaces 2023, IF **(**2021) = 6.2, Q1 Under Review

Challenges/Problems and Possible solutions: -

Future plan:

We aim to enhance collaboration with both Thai universities and industry partners, with the involvement of postdoctoral and postgraduate researchers for our initiative titled " Consortium for Nurturing Talent Pioneers in Materials Science and Technology to Drive Thailand to BCG Economy Year 2." This project involves collaboration with five Thai universities, 20 international partners, and seven industrial stakeholders, establishing a robust consortium dedicated to nurturing talents in the field of Materials Science and Technology.

Space Technology for Assessing the Potential of Forest Carbon Sinks to Achieve the Carbon-Net-Zero Emission

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 50%

Abstract: This research focuses on the use of drones equipped with LiDAR sensors for scanning forests in the Numtok Samlan National Park and census of trees and lianas in the permanent plot. The final result was the creation of a prototype that exemplifies the workflow of forest carbon assessment steps, along with a pipeline for the code used. The analysis of allometric equations, by comparing the Ogawa and Chave equations for estimating tree biomass, reveals that the Ogawa equation is superior. This leads to the opinion that the Ogawa equation should be used in the calculation. The analysis of the NDVI index using Sentinel-2 satellite helps in classifying forest clusters in the area. By applying the K-means method, consistent with LiDAR data, it aids in understanding the pattern of the distribution of vegetation in that area.

Rationales/Problem statements:

Various countries, including Thailand, grapple with the economic and welfare impacts of climate change. Thailand's commitment to achieving Carbon net zero by 2065 involves reducing greenhouse gas emissions, transitioning to renewable energy, adopting electric vehicles, and implementing waste management. However, solely relying on technological transformation poses a high risk of missing policy goals. Urgently, increasing nature-based capture and storage through the Land Use, Land-Use Change, and Forestry (LULUCF) policy is proposed. Forest restoration, though costly, can transform regenerating forests into crucial carbon sinks. Current methods for carbon storage evaluation face limitations, emphasizing the need for space technology like LiDAR remote sensing. A study in Khao Yai National Park, utilizing machine learning and ground data, aims to assess forest carbon dynamics, biodiversity, and ecosystem functioning. This groundbreaking research contributes to global efforts for net zero carbon policies, leveraging space-borne LiDAR technology and fostering international collaboration.

Objectives:

1. Develop remote sensing space technology to assess forest potential, that is more accurate and precise and covers a large area
2. Examine the causes of variation across spatial scales to assess the potential and causes of variation.
3. Examine the variation in tree diversity in different forms and the relationship between forests and the amount of biomass or carbon above ground.
4. Produce and develop highly skilled personnel in the S-curve group, including space and digital technology to meet the country's needs consisting of 2 post-doctoral researchers, and 1 post-master's researcher.

Progress/Findings/Results:

Sistronic Company deployed its drones equipped with multispectral and LiDAR sensors in Namtok Samlan National Park on 2 and 16 November 2023. Commencing work in November was crucial to avoid the strong winds and thunderstorms prevalent during the rainy season, which posed a high risk.

The fieldwork, conducted from 6-15 November 2023, involved creating 10 boundary plots

with dimensions of 20 meters by 200 meters and inspecting all trees with a diameter at breast height (Dbh) of ≥8 cm. As the area had been established as a permanent plot, data tracing was possible in 20-meter increments in rows. Researchers measured Dbh, painted plants, and mapped newly added trees, primarily relying on the azimuth angle measured from the original tagged tree.

To estimate biomass and determine the carbon stored, the team followed the principle of selecting allometric equations tailored to the specific forest area. The wood density, which ranged from 0.23–0.75 g/cm3 with an average of 0.52± 0.09 g/cm3, played a significant role in the evaluation due to its high variability.

In Thailand, Ogawa's equation, derived from mixed deciduous forests similar to those in the park, is available but does not include wood. Global equations like Chave et al. 2014 (Chave global) and Chave et al. 2005 for dry zones (Chave dry) are widely accepted. The research team compared Ogawa and Chave equations using tree data from previous censuses. Results indicated Ogawa's equation yielded the lowest aboveground biomass, followed by Chave dry and Chave global, respectively. While determining the superior equation requires direct field measurements, the conservative principle suggests using the Ogawa equation or possibly the Chave dry equation.

Namtok Samlan National Park encompasses both deciduous and evergreen forests. NDVI Vegetation Index analysis using Sentinel-2 satellite data during March, the driest time of the year, classified the forests. Images from 2016, 2019 (El Niño years), and 2023 revealed distinct NDVI index differences between forest types. Unsupervised K-means classification aligned with the NDVI results, providing consistent outcomes across the larger LiDAR image footprint and reference plot locations.

These findings illustrate the comprehensive approach taken by Sistronic Company, combining drone technology, allometric equations, and satellite data analysis to assess and classify the diverse forest ecosystems in Namtok Sam Lan National Park.

Conclusion:

1. The researchers conducted a field census on a 4 hectares permanent plot and made great progress. with almost all of it completed, but it still remains to check the accuracy again. Trees measured will have a dbh size of 8 cm or more.
2. The appropriate alometric equation analysis results are the Ogawa and Chave’s dry equations, and forest classification using NDVI is classified using machine learning methods, including K-means.
3. Sitronics scans images using drones equipped with LiDAR and Multispectral sensors. and helped with the analysis pre-processing This information will be sent to the researchers for further analysis.

Current Output:

1. Publications: Field data collection has been completed. and is in the process of analyzing data
2. Research tools and methods: Field data collection has been completed. and is in the process of analyzing data
3. Career advancement of science, research, and innovation personnel (next destination): Researchers enhance their skills. and experience in such research and received advice from experts from France
4. Influence on policy, practice, plan, and regulations: Creating guidelines for evaluating potential.

Challenges/Problems and Possible solutions:

1. Contract preparation begins approximately a month and a half before funding approval for research, allowing post-master researchers to commence work in June.

2. Researcher position must wait for the official announcement of results. This delay caused some skepticism, possibly explaining especially abroad researchers, may be unwilling to wait.
3. Setting aside 30% of compensation does not provide an incentive to move to another country for work (especially considering that the full amount of compensation is already not substantial). The announcement of the 30% deduction was not made from the beginning, contributing to researchers feeling dissatisfied and rejecting the position.

Future plan:

1. Analyze the data and check its accuracy again.
2. Write drafts of articles 1 and 2, and develop a workflow/pipeline for further evaluation of carbon accumulation in forests

National Postdoctoral/ Postgraduate System

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress:

The project's current progress is 58%, as compared to the proposed workplan and target results.

Abstract:

The National Science and Technology Development Agency (NSTDA) has one key mission on human resource development in major fields relevant to industrial needs, especially the disciplines well in line with core capabilities of NSTDA's 5 National Research Centers (BIOTEC, NECTEC, MTEC, NANOTEC and ENTEC) The responsible division of HRD at NSTDA, RPD, has been collaborating with the Program Management Unit for Human Resources & Institutional Development, Research and Innovation (PMU-B) on the very important initiative to accelerate highly-skilled researchers development through the project entitled "National Postdoctoral/Postgraduate System".

This project has received funding support from the NSRF via PMU-B [grant number B13F660064]. To drive this project with partner institutes, NSTDA has been in collaboration with Thammasat University and Thailand Institute of Nuclear Technology to provide total fellowships for 54 postdoctoral/postgraduate researchers to run industry-based research projects with 37 companies. These 54 projects are aligned with the 6 target industries of the First S-curve and the New S-curve: Biofuels and Biochemicals, Agriculture and Food, Medical Hub, Aviation and Logistics, Next-Generation Automotive and Smart Electronics.

NSTDA has also developed the mentoring system such that the fellowship recipients (postdoc/postgrad) conduct their research under supervisions of NSTDA's senior researchers and entrepreneurs from the collaborative companies. This way can effectively develop essential knowledge and skillset for the young postdoc/postgrad to pursue or even jump-start their research careers in the future.

Rationales/Problem statements:

As indicated above, it is very important and challenging for human resource development mission in Thailand, especially young researchers to have required knowledge or skill set relevant to practical working life in industries. With strong educational background of the young researchers after graduation, a designed program to build and enhance their technical skills and experiences, based on real industrial projects/problems would be an effective bridge for those young researchers to advance their practical capabilities in their future career. In a way, the systematic HRD program under the current project is clearly beneficial for both target industry development and national S&T capacity building.

Objectives:

1. To develop National Postdoctoral/Postgraduate System with preparation of science and technology workforces essential for the development of target industries (First S-curve, New S-curve, BCG and Frontier Science and Technology),
2. To build collaboration and implement the system through working with partners from academia, government, and private sectors, both domestically and internationally, to strengthen higher S&T human resource development consortium in Thailand, and
3. To develop postdoctoral and postgraduate researchers with technical knowledge and

practical skills for target industries using two-dimension mentoring system (senior researchers combined with engaged entrepreneurs) for benefits of their future S&T professionals as well as for supporting R&D based Thai industry.

Progress/Findings/Results:

1. NSTDA by 5 National Research Centers and NSTI, together with partnering institutes (Thammasat University, and Thailand Institute of Nuclear Technology) under this project were formed as a consortium for postdoc/postgrad development. Senior researchers of participating institutes play key roles as mentors of the fellowship recipients of 54 young researchers under 37 projects. These industry-based projects have major goals in developing new products/process or providing innovative solutions for problem solving cases.
2. Based on the approved proposal by PBU-B, all 54 postdoctoral/ postgraduate researchers were recruited. Formal documents and contracts were also completed.
3. Research projects have been performed under developed mentoring system by both senior researchers (PI) of the projects and collaborative entrepreneurs/company representatives. It is intended to create this type of mentoring mechanism to foster research ecosystem under this project
4. Essential training courses are designed and developed to help improve existing skills or adding extra arrays of capability for postdoctoral and postgraduate researchers. These include research and quality management, business and management skills, and other soft skills such as presentation tools & tricks through both online and onsite training platforms.
5. Overall project has been managed by quarter-based following up and monitoring of each sub-project. The HR coordinators of each participating institutes/research centers work closely with the project's main coordinator of NSTDA (RPD) to ensure timely and effective supports. This mechanism is key in managing risks and to drive towards successful results or committed outputs.
6. Based on the 6 month report, work progress on achieving high quality output of 90 items is approximately 50-60%, as compared to completion. These include 24 publications, 25 patents, 35 prototypes and 6 technology transfers upon 1 year project completion.

Conclusion:

Based on the 6 month work, the project on "National Postdoctoral/Postgraduate System" by NSTDA has 58% progress, as compared to the proposed workplan. The overall project covers 54 fellowship recipients under 37 industry-based sub-projects. Key mechanisms used to conduct this project in an effective way are as follows: 1) Formation of the participating institutes as a consortium, 2) Using two-dimension mentoring system (senior researcher and entrepreneurs from the collaborative company), 3) Quarter-based follow-up/monitoring with effective supports by the project coordinators and 4) Essential training course provided for postdoc/postgrad researchers. Progress of all key results (high quality outputs of 90 items) is 50-60% (as detailed below). In summary, NSTDA has high anticipation to achieve all committed results of the main project. Hopefully, our experiences and all integrated components under this project can be useful in shaping an effective model for the National Platform of the Postdoctoral/Postgraduate System.

Current Output:

Considering the total committed high quality outputs of 90 items, including 24 publications, 25 patents, 35 prototypes and 6 technology transfers, technical preparations of these outputs by the fellowship recipients are underway. Work progress is approximately 50-60%, as compared to completion.

Challenges/Problems and Possible solutions:

1. Some candidates of postdoctoral and postgraduate researchers (10), refused to receive the fellowships prior to starting the project, due to other offers while waiting for final announcement. Some fellowship recipients (2) requested to stop the contract during running the projects. The first part involving process duration shall be considered and reviewed, if possible, to reduce such risk/effect.
2. Criteria of some outputs may require more time for their processes. Total outputs may take longer than the project duration of 1 year for completion, such as publication to be accepted, and patent to be officially filed. Thus, flexibility or more time provided for the fellowship recipients would be very helpful.
3. If budget for some important expenses such as welfare of the fellowship recipients, can be allocated at the beginning of the project, this would be very helpful under the budget status of the organization.
4. If possible, may the PMU-B consider providing additional essential budget for paper publishing and IP management or patent filing expenses.

Future plan:

1. Continue the effective mentoring and supporting mechanisms provided to postdoc/postgrad researchers and use the quarter-based following up and monitoring approach to ensure that all committed key results can be achieved.
2 Organize phase II plan of skill development using the online platform for other essential knowledge/skills, in order to enhance core competency of the postdoc/postgrad researchers.

Study and Development of Porous Nanofibers, Graphene Oxide Quantum Dot Nanofiber Composite, and Metal Doped Graphene Oxide Quantum Dot Nanofiber Composite for Carbon Dioxide Reduction and Capture

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 60%

Abstract:
Quantum Dots (QDs), are exotic nanostructures with tunable quantum efficiency, size range, and fluorescence emission that can be employed for diverse applications such as semiconductors, supercapacitors, photodetectors, photodiodes, solar cells, fuel cells, bioimaging, catalysis, sensors, and theranostics. However, the hazardous reaction conditions and the toxic chemicals used for the synthesis and stabilization of the QDs used in the above methods make them unsuitable for biomedical applications. Biogenic approaches for the fabrication of QDs are attractive. Diverse phytochemicals present in the plant extract may play a critical role in the synthesis, shape evolution, and stabilization of the biogenic QDs are also covered. In view of the background, the following report gives an elaborate account of the synthesis of carbon quantum dots (CQDs) using *Syzygium samarangense* popularly known as Java apple. The CQDs were characterized and will be used further to incorporate within electrospun polymeric nanofibers for carbon dioxide reduction and capture.

Rationales/Problem statements:
Tremendous increase in the green house gases has led to global warming which is affecting the nature and health. The increase in the carbon dioxide in the atmosphere at an alarming rate has emphasized on the need to develop sustainable strategies for carbon capture. Hence, nanotechnology driven solutions are being designed as it is thought to be rapid, efficient and advanced. Extensive efforts to develop composite nanostructures using polymers, metal, metal-oxide and other nanomaterials aim to capture carbon dioxide from the atmosphere and reduce air pollution. Although there are various methods for biological synthesis of carbon quantum dots (CQDs), *Syzygium samarangense* has not been explored yet. Hence, it would be interesting to incorporate the phytogenic CQDs into electrospun polymeric fibers composed of polystyrene (PS)/polyethylenimine (PEI). This advanced membrane with desired morphological and functional properties may play a significant role in carbon dioxide reduction and capture.

Objectives:
(1) Synthesis and characterization of the carbon quantum dots.
(2) Synthesis of polymer nanofiber composite using electrospinning and their characterization.
(3) Determination of carbon dioxide reduction and capture efficiency.

Progress/Findings/Results:

Synthesis of CQDs:
The fresh Java apples were used for the preparation of the plant extract. The stepwise processing of the fruits was carried out eventually getting the pure fruit juice which was used for further CQDs preparation. The CQDs were synthesized by direct hydrothermal treatment of the fruit juice at 180 °C for 36 h. Then the resulting CQDs were collected by

filtration with a 0.22 µm membrane that showed brown colour in visible light while it exhibited bright fluorescence under UV light. The use of Java apple juice as a natural precursor and low synthesis temperature allowed for the highly scalable and sustainable synthesis of CQDs.

UV-visible spectroscopy:

An aqueous dispersion of the CQDs was highly stable without any sign of precipitation even after four months. On irradiation with 365 nm UV light, the aqueous solution of CQDs showed an intense greenish blue color indicating its potential in the optoelectronic and biomedical fields. The UV-visible spectroscopy revealed a sharp peak at 283 nm which indicated the successful synthesis of the CQDs from the plant extract. Further, the UV-Vis absorption data was fitted by Tauc's formula for direct band gap evaluation.

FTIR analysis:

The Fourier transform infrared (FTIR) spectrum showed the presence of significant surface functional groups. The merged peaks at ~1595 cm−1 were assigned to C=O and C=C stretching in the conjugated structure. The C=O and C-O stretching vibrations at ~1595 cm−1 and ~1405 cm−1, respectively, indicate the presence of oxygenated carboxyl and hydroxyl functional groups. Furthermore, the intense band at ~3393 cm−1 can be assigned to typical –O-H stretching vibrations. The doublet at ~2937 represents C-H stretching. The broad band at ~618 cm−1 was ascribed to =C–H stretching.

TEM analysis:

The morphology and microstructure of the CQDs were investigated using transmission electron microscope (TEM) analysis. Typical TEM image exhibited that the CQDs were nearly monodispersed and almost spherical. The CQDs exhibited a narrow size distribution in the range of 4–7 nm.The CQDs were highly crystalline with a d-spacing of 0.24 nm.

Conclusion:

Biogenic CQDs with attractive morphological and optical properties hold great promise for biomedical, environmental, and industrial applications. The route for synthesis is rapid, efficient, and environmentally benign where the generated CQDs are highly fluorescent and biocompatible. The smaller size of the biogenic CQDs makes them attractive for easy uptake and elimination after activity from the cells. However, in order to ensure their clinical translatability, thorough toxicity studies along with pharmacokinetic and pharmacodynamic investigations are warranted. Moreover, the various synthesis parameters like fruit juice concentration, reaction time, temperature, and pH, should be carefully optimized to improve scalability that would ensure higher yield and decrease the production cost. Incorporating the biogenic CQDs into polymeric nanofibers can yield significant properties for ideal carbon dioxide reduction and capture. Thus, with a systematic approach coupled with global R&D and commercialization efforts, biogenic CQDs have a high probability to revolutionize the future of environmental nanotechnology.

Current Output:

During the period 2 manuscripts were published in Frontiers in Chemistry (**Impact Factor : 5.5; Q1 category journal**), and 10 book chapter manuscripts were submitted and accepted in books from reputed publishers like Elsevier, CRC Press, Taylor and Francis, De Gruyter, and Springer. Data was also presented in 2 international conferences in Philippines and Indonesia.

Publication in Q1 category International Journal:

Ghosh S, Nandasana M, Webster TJ, **Thongmee S** (2023) Agrowaste generated biochar for the sustainable remediation of refractory pollutants. Frontiers in Chemistry. 11:1266556.

Ghosh S, Turner RJ, **Thongmee S** (2023) Editorial: Biofabrication of nanostructures for environmental, agricultural, and biomedical applications. Frontiers in Chemistry. 11:1283676.

Challenges/Problems and Possible solutions:

Challenges:

1) Achieving the accurate viscosity of the polymer mixture for efficient electrospinning is challenging.

2) Getting the desired shape, structure, and surface feature of the electrospun polymeric fiber will be critical for its catalytic activity.

Possible solutions:

Parameters such as polymer concentration, the tip-to-collector distance, voltage range, feed rate of the solution, and rotation speed of the metallic cylinder for collection will be optimized to achieve desired properties of the polymeric fiber during the electrospinning process.

Future plan:

Incorporation of the phytogenic CQDs into the polymeric fibers developed using electrospinning will be the next target. The CQDs impregnated fibers will be characterized using scanning electron microscopy. The carbon dioxide reduction and capture efficiency of the novel nanocomposite fiber will be evaluated.

Enhanced Performance of Full-time Postdoctoral/Postgraduate Researchers in Frontier and Translational Research in Suranaree University of Technology

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Project duration: 1 year, from 1 April 2023 to 31 March 2024

Current progress: 52%

Abstract:

This project aims to enhance the performance of full-time postdoctoral/postgraduate researchers (FtRs) at Suranaree university of Technology to produce high-impact research and innovations. Currently, there are 54 FtRs working in several research fields of (i) energy and materials, (ii) engineering, (iii) food and agriculture, (iv) health and medicines, and (v) frontier research. In the past 6 months, these FtRs have generated variety of research outputs including (i) 5 accepted papers in top 10% or Q1 journals indexed in Scopus, (ii) 1 scientific prototype, (iii) 3 international research consortiums, and (iv) 16 poster and oral presentations. Besides, 4 FtRs have been promoted to an academic position with 5-year contact. With this status, they have job security and professional carrier paths as well as other profits comparable to lecturers (e.g., health insurance and provident fund). This not only retains our talented FtRs but also encourages others to improve their performances.

Rationales/Problem statements:

For sustainability and competitiveness, there must be sufficient high-quality researchers working in the country. In 2021, Thailand has 25.1 researchers to 10,000 population, which is significantly inferior to other developed countries in Asia, such as 115.1 and 79.5 for Taiwan and Singapore, respectively. This project targets to enhance not only the number of researchers in frontier research but also to produce high-impact publications and innovations. Besides, strong research collaborations at the national and international levels are focused to generate interdisciplinary project for strategic funds and/or international grants. In the university level, the improvement of the ranking (THE, QS, and Nature index) is achieved.

Objectives:

1. To enhance the performance of full-time postdoctoral/postgraduate researchers (FtRs).
2. To produce high-impact publications in top 10% and Q1 journals, prototypes, and innovations.
3. To establish national and international research collaborations and consortiums.
4. To improve the ranking (THE, QS, and Nature Index) of Suranaree university of Technology (SUT).
5. To create the friendly research atmosphere for FtRs in SUT.

Progress/Findings/Results:

This project started with recruiting 55 FtRs in April 2023. To be sure that we can deliver all research outputs to PMU B on time, all FtRs and their mentors must sign an agreement mentioning the research outputs, project duration, and budget. In the meantime, 19 FtRs have been replaced due to resignations for new jobs, agreement rejection, and limited grant allocation from the university. Currently, 54 FtRs are in the project, and they have produced several research outputs as mentioned in the abstract and current output sections. For the other vacancy, the recruitment is planned by mid December 2023 in accordance with the main FtRs grant from the university. In terms of budget plan, the payment will be allocated when FtRs deliver their research outputs, mainly the top 10% or Q1 papers indexed in

Scopus. After collecting all data from FtRs and their mentors for the progress report, 5 FtRs with the accepted papers will be granted 20% of the salary (6 months period). Moreover, the travel allowance for FtRs, who join the Brainpower Congress will be granted. Thus, there will be the progress of budget allocation included in the next report.

Conclusion:

For the past 6 months, 55 FtRs were recruited, 19 FtRs were replaced, and 54 FtRs in the several research fields were currently in the project. These FtRs delivered the research outputs of scientific papers in top 10% and Q1 journals, prototypes, research consortiums, and presentations at the conferences. Since our system was different from other institutes, there were several changes in the project. We would like to thank PMU B for understanding and approving our requests during the project period. We will do our best not only to deliver all outputs on time but also to enhance the performance of FtRs and produce high-impact research work.

Current Output:

1. 54 full-time postdoctoral/postgraduate researchers.
2. 5 accepted papers in top 10% or Q1 journals indexed in Scopus.
3. 1 scientific prototype.
4. 3 international research consortiums.
5. 16 poster and oral presentations at national and international conferences.
6. 4 FtRs promoted to an academic position with 5-year contact.

Challenges/Problems and Possible solutions:

- The project duration is short. Some FtRs have rejected the agreement since they are not sure if they can deliver the output on time.
- The FtR scholarship from the university is very competitive. Some FtRs and mentors cannot continue because they are not granted.

Future plan:

- Recruitment one FtR to reach the target committed to PMU B (55 FtRs).
- Follow up the research progress of all FtRs.
- Some replacements are probably considered due to the reasons mentioned in the progress/finding section.
- Budget allocations to the FtRs, who join the Brainpower congress and deliver the research output.

The Studies and Applications of Artificial Intelligence in Alleviating Problems and Improving the Quality of Life of Thai People

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Project duration: 1 year, from 1 April 2023 to 31 March 2024
Current progress: 30.75%

Abstract:

During the first 6 months, activities under the project are divided into 2 main activities: Main activity 1 is the development of an application that can check nutritional information and recommend food quantities using artificial intelligence techniques for people with diabetes, obese people, and those who love health. The second is studying and applying artificial intelligence to help alleviate online fraud problems: in the case of notification of access to risky websites.

Main activity 1: Researchers write a research article to submit to an academic conference for consideration. which was accepted to present the said research article at the international academic conference ICoABCD 2023 held on Bali Island, Indonesia.

Main activity 2: Using the PRISMA model technique, reviewed both domestic and foreign literature, including investigating artificial intelligence techniques to find relevant strategies for developing a prototype system that will assist in lessening the problem of online fraud.

Rationales/Problem statements:

Artificial intelligence technology is applied Image processing technology and information technology related to medical and public health work It will be another channel that will help Thai people have a better quality of life. Therefore, the research team foresees that a prototype nutrition application is designed for people with diabetes, obese people, and those who love health. It will help make patients and those interested in health care have a better quality of life.

Artificial intelligence is applied to the concept of website content, it is one of the key features used to classify websites that are at risk. It will help make the classification of at-risk websites more accurate. This is considered another way to help alleviate the problem of online fraudsters for the Thai people.

Objectives:

1) Conducting a case study and developing a nutrition application for individuals with diabetes to examine and implement artificial intelligence to help alleviate health issues, obese people, and those who care about their health.
2) Researching and using artificial intelligence to help citizens who use the internet and visit different websites with their online fraud issues by, for example, alerting them when they are about to access unsafe websites.
3) Assisting in the preparation of post-graduate researchers with expertise in artificial intelligence to work in the digital industrial sector.
4) To contribute to and help improve Thailand's academic subject of artificial intelligence. and write artificial intelligence research papers for publication in international academic publications.

Progress/Findings/Results:

Main Activity 1: Relevant literature was examined and reviewed within the first six months. Planning the experimental design, writing and submitting a research article to present at the international academic conference ICoABCD 2023 in Indonesia, and being admitted to attend the abovementioned academic conference on November 13 - 14, 2023 via the online system. It will be expanded into a draft research article for submission to academic journals in the Scopus Q1 database. Furthermore, certain prototype systems have already been created and tested.

Main Activity 2: Using the PRISMA model technique, reviewed both domestic and foreign literature, including investigating artificial intelligence techniques to find relevant strategies for developing a prototype system that will assist in lessening the problem of online fraud. The emphasis is on alerting users to potentially dangerous websites. In addition, we surveyed and collected information from financial organizations' and banks' websites. However, gathering information on Thai phishing websites is difficult. As a result, instead of studying foreign material, we will imitate the URLs of phishing websites that mimic the websites of financial organizations and banks. To be used in research articles. This is presently being worked on.

Conclusion:

Main activity 1: Researchers write a research article to submit to an academic conference for consideration. which was accepted to present the said research article at the international academic conference ICoABCD 2023 held on Bali Island, Indonesia.

Main activity 2: Using the PRISMA model technique, reviewed both domestic and foreign literature, including investigating artificial intelligence techniques to find relevant strategies for developing a prototype system that will assist in lessening the problem of online fraud.

Current Output: -

Challenges/Problems and Possible solutions:

Management of various parts has taken longer than expected. To speed up the task, the research team convened weekly project follow-up meetings. and the ability to deliver output and outcomes on time as defined in the contract.

Future plan:

The research team convenes weekly project follow-up meetings. and the ability to deliver output and outcomes on time as defined in the contract.

Human Capacity Development for Smart City and Digital Economy Promotion Through Urban Living Lab and Social Innovation Platform

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Project duration: 1 year, from 1 August 2023 to 31 July 2024
Current progress: 40%

Abstract:
The development of cities under the Smart City concept has gained prominence post-COVID-19. In 2023, the digital industry in Thailand is expected to grow by 24% from 2022, reaching 450 billion baht. This growth is categorized into two sectors: 1) Industries driven by digital needs of businesses, and 2) New industries for export in the Eastern Economic Corridor (EEC), especially in services. Analysis by the Digital Economy Promotion Agency (depa) highlights the Health-Tech and EdTech sectors' growth during the pandemic, driven by the population's demand for digital skill enhancement.
Smart City development extends beyond digital infrastructure, encompassing access and user skills across community networks, education, government, and private sectors. This comprehensive approach integrates data, technology, and innovation, focusing on holistic urban development that encompasses economic, social, and environmental dimensions.

Rationales/Problem statements: -

Objectives:

1. Develop human resources with the capacity to analyze the instruments and procedures used in the design and development of cities.
2. Enhance knowledge institutions and human resources in the areas of data management, analysis, and urban development application.
3. Advocate for the expansion and transformation of urban development sectors, with the aim of fostering job growth in research institutions, academic institutions, science parks, private organizations, and governmental bodies.
4. Enhance the capacity of human resources to formulate and implement regional economic and social development plans as well as national strategic plans.

Progress/Findings/Results:

This project emphasizes two main aspects of human development: 1) Enhancing the capabilities of researchers, and 2) Developing tools and processes for research work.

1. **Enhancing Researcher Capabilities:** emphasis on developing tools and training programs for researchers, enabling them to apply their knowledge and tools for efficient and impactful sub-project development in economic and social aspects.
    - **a** Development of curricula based on the World Economic Forum framework, divided into lecture activities and mini projects.
        I. Technology adoption and data management
        II. Critical thinking and problem-solving

III. Self-management focuses on active learning and flexibility.

b Implementing a coaching system

2. **Developing Tools and Methodologies for Research Application:** developing tools and processes for research work to implement research into practical, local-level applications.
    - **a** Accessible and usable data, technology/innovation, and platforms.
    - **b** Knowledge enhancement to develop skills within organizations (government, private sector, education, and community) through training programs and practical experiments.
    - **c** Collaborative networks with shared urban development goals, facilitate the exchange of knowledge, tools, data, and innovation within and outside the network.
    - **d** Innovation testing areas.
    - **e** Monitoring tools for tracking and evaluating project progress.

    These five components are critical discoveries for translating research into practical action and urban development at an operational level.

Conclusion:

This research project primarily concentrates on developing a curriculum aimed at enhancing researcher capabilities, with two objectives: **1)** Cultivating skills relevant to current environmental, technological, and economic trends, and **2)** Advancing abilities in creating tools, data, and innovations for research applicable to local experimental settings. The project has successfully implemented training modules, including lectures, mini-projects, and a structured coaching process. Six researchers have integrated these methodologies, collaborating with various local sectors in Bangkok for practical tool application and testing. The team is finalizing research topics for journal submission, scheduled for early February **2024.**

Current Output:

- Course for Researcher Development Skill
- Prototype Area (To Test Theory and Tools)

Challenges/Problems and Possible solutions: -

Future plan:

- Develop human resources in the public, private, and academic sectors to support Smart City initiatives via a system of coaching and training.
- Propose the implementation of operational aids for the public, private, and community sectors, including urban databases, SIA evaluation tools, and community health survey instruments.
- Foster and develop a new generation of urban developers from the public, private and community sectors through collaboration with local networks to drive area-level initiatives.
- Perform market research to develop a specialized curriculum for "Human Resource Development in the Research sector" that specifically addresses the sector's evolving requirements.

Upgrading Research Manpower Capability for National Research Institutes under Thailand Academy of Sciences

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Project duration: 4 years, from 12 October 2023 to 11 October 2027
Current progress: 18%

Abstract: Thailand Institute of Nuclear Technology, National Astronomical Research Institute of Thailand, Synchrotron Light Research Institute, Mahidol University, and Ofiice of the Ministry of Higer Education Research Science, and Innovation have joined forces to recruit graduate students under the 3rd perspective of Thailand Academy of Sciences (TAS). This year is the starting of the project and the recruitment of the first cohort of graduate students under TAS. Progress and status of the project will be reported.

Rationales/Problem statements:

Tremendous growth of research and development in science and technology is a key factor for a development of the country including economic, sociological, and economical aspects. Regarding to the rapid change of global competition, the enhancement of scientific and technological research is urgently required. Thailand Academy of Sciences (TAS) is established to be a central networking organization for bridging researchers and scientists from various national research institutes and universities to work together as a unit. In addition, an integrated utilization of existing national infrastructures will improve the basic knowledge of sciences and technology, and the fundamental development of human resources of the country. Consequently, it can leverage and enhance the global competitive ability of the whole country. TAS will be proceeded in 3 main perspectives as follow:

1) Knowledge network of sciences and technology for a development of the country
2) Frontier research for an improvement of global competitiveness
3) Creation and development of high-performance human resources for a development of the country.

Herein, the recruitment of Ph.D. students under the TAS program is one of the main activities to fulfil the 3rd perspective. TAS Ph.D. program will provide the targeted creation of high-performance human resources by employing the integration of infrastructures at national research facilities with high-quality personnel from universities. TAS will be a key mechanism allowing national institutes to issue the educational degrees and develop the key human resources for such urgently important disciplines of the country. The graduates from TAS program should have high qualifications and are expected to achieve their successful career path in governmental institutions, business sectors, and self-employment. TAS is a central unit of the academic and research networking consisting of universities, national research institutes, excellent centers, policy agencies, research funding agencies, and their international collaborations. TAS will proceed under the concept of “work with creativity, enthusiasm, and passion” to provide a value creation to move Thailand to be one of the developed countries within 2027.

Objectives:

The graduates will have qualifications:

• Have good attitudes in professional settings and enhanced sense of morality and ethics,
• Demonstrate in-depth, integrative knowledge and skills in using appropriate research methodology and tools in the field of study in both broad and specific contexts as well as

internal and external factors related to innovation.
• Create scientific research and/or innovation which serves the need of the Nation based on in-depth, integrative knowledge, scientific analytical skills, and critical thinking.
• Build up capacity to be an ASEAN and global citizen, be able to adapt to the future work efficiently and capable of being in a teamwork both as a leader and a follower to drive innovation forward with a high sense of social responsibility.
• Use information technology, numerical and statistical methods in analysing scientific data and comprehensively communicate relevant knowledge and academic findings in oral or in written form to diverse audiences

Progress/Findings/Results:
A memorandum of action between Office of the Ministry of Higher Education, Science, Research and Innovation, Mahidol University, Thailand Institute of Nuclear Tehcnology, National Astronomical Research Institute of Thailand and Synchrotron Light Research Institute has already been settled and signed. An executive committee of the program and instructors and lecturers is being formalized.

Conclusion: Certain activities has already been started for about two months. Overall progress of this year is about one fifth. There are quite a few challenges to be overcome. If the hurdles were overcome, it should pave the easier way for similar action in the future.

Current Output: List of applicants to be drafted by the selection committee and approved by the program executive committee.

Challenges/Problems and Possible solutions:
There are at least three challenges and hurdles that the project is facing now. One is the program is offering lower payroll to students. This may be unattractive and may result in much smaller pool of potential and talent candidates. Working across few institutes is not seamless in general, each institute needs to work out internal process like budgeting division and approval of curriculum even though the program is endorsed top-down as strategic activity.

Future plan: Registration of students, Formally start curriculum activities, Put in place process with quality control and governance.

Light Nuclei Formation in Heavy Ion Collisions and the Formation of Cosmic Structures – From Big Bang to Galaxies

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 77%

Abstract: Heavy-ion and astrophysics are not only closely related scientifically, but also share many methodological similarities. Although the standard Big Bang model describes the various stages in the evolution of our universe, we still lack a precise understanding of structure formation processes ranging from hadronization and light nuclei formation to the large-scale dynamics of galaxies. We describe these using an array of advanced transport models, hydrodynamics, and modern machine learning algorithms that incorporate specific features of the relevant processes. With this setup, we can identify signals for a phase transition in strongly interacting matter, decode the nucleosynthesis mechanism, and give precise geometrical descriptions of active galactic nuclei. Collaborations with domestic and international institutions are expected to strengthen existing partnerships and promote regular and fruitful exchange between researchers and students.

Rationales/Problem statements:

Over the past several years, faculty members from the school of physics, Suranaree University of Technology, have collaborated with European universities on various research projects, such as heavy-ion physics, galactic dynamics, and astrophysics of black holes. This project aims to strengthen bilateral research collaborations and expand them into trilateral ones. The goal is to establish a strong regional collaborative network and to promote interdisciplinary research connecting particle and heavy-ion physics with studies on galactic-scale phenomena and the mechanisms for releasing high-energy particles from supermassive black holes at galactic cores. The integration of knowledge from these diverse fields is expected to advance a more comprehensive understanding of nature.

Objectives:

1) To study the mechanisms of light nuclear formation in heavy ion collisions
2) To study the mechanism of galaxy evolution
3) To develop a common framework based on hydrodynamics for studying micro- and macro- systems, from the Big Bang to galaxies

Progress/Findings/Results: The research in this project has introduced a new interpretation of the coalescence parameter B_2 for light nuclei formation in heavy-ion collisions at center-of-mass energies below 5 GeV. This interpretation reduces the discrepancy between the fireball volumes extracted from HBT measurements and the volumes extracted from the coalescence factor. We studied the harmonic flow coefficients v_1 to v_4 in semi-peripheral Au+Au collisions at a beam energy of 1.23AGeV. In contrast to ultra-relativistic collision energies, we found strong correlations between all investigated flow coefficients based on an event-by-event selection of the mid-rapidity final state elliptic flow of nucleons. In the same energy regime, we developed a method to distinguish coalescence from thermal production of light clusters using isospin triggering. The observation of a non-constant deuteron yield as function of isospin fluctuation in experiments can be used as clear confirmation of coalescence over thermal production.

We studied the QCD critical end point and first-order phase transition with a fluid dynamic expansion coupled to the explicit propagation of the chiral order parameter sigma

via a Langevin equation. We found that a critical end point clearly imprints into cumulant ratios over a wide range of center-of-mass energies. Furthermore, the pion-to-proton ratio has been identified as a potential signal for a non-equilibrium first-order phase transition in heavy-ion collisions. Utilizing a Bjorken expansion, the research demonstrates a significant multiplicity ratio enhancement during a phase transition due to enhanced entropy production, distinguishing it from a smooth crossover and even a critical point. By mapping the initial and final entropy-to-baryon number ratio to a hadron resonance gas, we could quantify the shift as a function of beam energy.

In astrophysics, we have successfully applied machine learning models, including dictionary learning and support vector machines to predict the AGN source height using PSD data, even when the PSD has a bending power-law shape.

Neural network models were also developed to accurately predict the black hole mass in AGNs using various features, with higher accuracy than traditional linear regression methods. Additionally, a PSD model was developed to explain the X-ray variability in IRAS 13224-3809. The findings indicate that the corona height changes with luminosity, the energy spectrum becomes softer as the corona height increases, and the PSD normalization is correlated with the fractional excess variance and the PSD bending index. Furthermore, we investigated the utilization of the Granger causality test to reveal intrinsic X-ray reverberation lags in active galactic nuclei, specifically in the case of IRAS 13224 −3809. Granger lags are a promising way to measure the intrinsic lags, they provide evidence of coronal height variability within each individual observation. Including the improvement of the RFR ML- model, this model has a high prediction accuracy on the coronal height in two AGNs using X-ray reverberation features.

We investigated the changing geometry of the accretion disc in the X-ray binary GX 339-4 during the 2015 X-ray outburst, using spectral and timing models, and found that the truncation radius of the disc increases towards the end of the outburst.

Conclusion:

In the past two years, research was conducted as part of this project on relevant aspects of heavy-ion collisions and astrophysics. The output has been published in Q1 journals including Physical Review C, The European Physical Journal C, Physics Letters B, Monthly Notice of the Royal Astronomical Society (MNRAS), and The Astrophysical Journal. Moreover, five schools and workshops were organized. Researcher and student exchanges are ongoing.

Current Output:

• 10 publications in Q1 **(**SUT as corresponding author for 8 publications**)**
• 2 schools and 3 workshops
• 1 Double Degree program in Physics between SUT and Goethe University

Challenges/Problems and Solutions (if any):

Future plan:

• Calculate distributions, ratio, rapidity, and transverse momentum of light nuclei (deuteron and triton) and compare with experimental data
• Develop a model for galactic analysis, with freely accessible algorithms and database
• Develop ML algorithms for reverberation studies to predict the corona and accretion mass disk system and implement an automatic data optimization
• Analyze and compare the results of the developed models with other data
• Develop a mechanistic model for galactic formation from heavy-ion collisions
• Develop ML algorithms for reverberation mapping as public code to study physical phenomena in AGNs

BRAINPOWER CONGRESS 2023

ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้านการพัฒนางานวิจัยขั้นแนวหน้า (Engineering และ Chemistry)

Synthesis, Mechanism of Action and Target Identification of Anti-hyperlipedemic Statin and Preussin Derivatives from the Soil-derived Fungus *Aspergillus sclerotiorum* PSU-RSPG178

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Project duration: 3 years, from 1st November 2021 to 31st October 2024

Current progress: 73.5 %

Abstract: *α,β*-Dehydromonacolin S (**1**), *α,β*-dehydromonacolin K (**2**) as well as their opened forms and alkyne probes were successfully synthesized. The statin-**1 opened form** exerts hepatic lipid-lowering effects similar to that of fenofibrate whereas the statin **1** and its probes had no effect. For the CFTR inhibitory activity, the statin **2** and its probe significantly inhibited forskolin-induced fluid secretion in 3D human colonoid to the same level as GlyH-101, a reference CFTR inhibitor. In addition, preussin (asperidine B, **3**), eleven derivatives and three chemical probes were successfully synthesized. Among the derivatives, preussin B significantly inhibited cholesterol transport across jejunal epithelial cells and in rat similar to ezetimibe, a cholesterol absorption inhibitor. Moreover, all three probes exhibited lipid-lowering activity in intestinal Caco-2 cells using high content imaging similarly to compound **3**. This presentation will focus on the synthesis of compound **3** and its derivatives as well as their lipid-lowering effect.

Rationales/Problem statements: *α,β*-Dehydromonacolin S (**1**), *α,β*-dehydromonacolin K (**2**) and preussin (asperidine B, **3**) were isolated from *Aspergillus sclerotiorum* PSU-RSPG178 by our research group. The statin **1** displayed higher ability in lowering total cholesterol, triglyceride, LDL and fatty liver as well as increasing HDL in the high fat-diet-fed rat models than lovastatin. Interestingly, the ability in lowering fatty liver is uncommon for statins. Surprisingly, compound **3** suppressed intestinal absorption of lipids *in vitro* and *in vivo* in rats, which was comparable to ezetimibe, a cholesterol absorption inhibitor. Importantly, the statin **2** significantly inhibited cAMP-induced chloride secretion in T84 cells and *in vivo* in mouse models of secretory diarrheas. Accordingly, mechanisms of action and identification of molecular targets using proteomic approach are of interest. The results obtained will enable efficient optimization of these compounds towards lead compounds as well as the discovery of novel efficacious drug targets for both metabolic syndrome and diarrheas.

Objectives: To synthesize the bioactive statins **1** and **2**, and asperidine B (preussin, **3**) as well as analogues of compound **3**; to optimize lipid-lowering effect of compound **3** and analogues by performing structure-activity analysis; to prepare the alkyne probes of compounds **1** and **2** and **3**; to identify molecular targets of compounds **1**, **2** and **3** using proteomics approaches**;** to investigate anti-diarrheal efficacy of compound **2** in human intestinal epithelium using human enteroid models and lipid-lowering efficacy of the most potent derivative of compound **3** *in vivo*.

Progress/Findings/Results: *α*,*β*-Dehydromonacolin S (**1**), *α*,*β*-dehydromonacolin K (**2**), the opened form of **1** (**1-opened form**), three alkyne probes of **1** (**probes 1-1 - 1-3**), one alkyne probe of **2** (**probe 2-1**) and one alkyne probe of statin **1-opened form** (probe **1-4**) were successfully synthesized. Verification of lipid-lowering effect of **1**, **1-opened form** and **1** probes using the fluorescent-nile red and flow cytometry indicated that **1, 1-opened form, probe 1-2,** and **probe 1-3** did not cause cell toxicity. Interestingly, **1-opened form,** but not **1**, showed significant decreased in intracellular lipid content similarly to that of positive drug, fenofibrate. Nonetheless, neither **probes 1-2** nor **1-3** had hepatic lipid-lowering effects. For **2** and **probe 2-1**, they significantly inhibited forskolin-induced fluid secretion in a 3D human colonoid to the same level as GlyH-101, a reference CFTR inhibitor. In addition, **2** may partially inhibit CFTR-mediated chloride secretion *via* CFTR negative regulator such as AMPK activation. Besides the synthesis of statins and their probes, preussin (asperidine B, **3**), eleven derivatives (**TP1**-**TP7** and **TP12**-**TP15**), three alkyne probes of **3** (**TP8**, **TP10** and **TP11**) and one alkyne probe of **TP5** (**TP9**) were successfully synthesized. Seven derivatives (**TP1**-**TP7**) had strong potential to inhibit cholesterol absorption similar to compound **3** and ezetimibe on fluorescent-micelle cholesterol transport in intestinal Caco-2 cells using high content imaging without cytotoxicity. Among **TP3**-**TP7**, **TP5** (preussin B) had the highest efficacy to interfere bile acid binding capacity and the highest efficacy for down-regulating HMGR gene expression, and markedly reduced PPARα gene expression for 6-fold higher than control or untreated HepG2 cells. Like compound **3**, **TP5** inhibited intestinal cholesterol absorption mediated by LXRα activation. Furthermore, the combination of **TP5** and fenofibrate had no further reduced cholesterol absorption, indicating that **TP5** may activate PPARα resulted in reduced cholesterol absorption. Unlike LXRα, 2 μM of GW6471 did not blunt **TP5**'s effect, suggesting that **TP5** reduces intestinal cholesterol absorption mediated by activation of transcription factor LXRα, without any interference with PPARα, resulting in interfering NPC1L1 membrane trafficking. Additionally, **TP5** inhibited cholesterol transport across jejunal epithelial cells with the highest potency than other derivatives and showed comparable activity to ezetimibe. Finally, **TP5** significantly reduced the plasma [^{3}H]-cholesterol level similarly to ezetimibe in rats. Besides **TP5**, both **TP1** and **TP2** displayed similar effect on intestinal cholesterol absorption in rats to that of ezetimibe. They also reduced oxidative stress in the similar degree to that of a positive non-enzymatic antioxidant, vitamin C, and induced antioxidant gene expression. Interestingly, **TP2** showed higher inhibitory activity against α-glucosidase by approximately two-fold than **TP1,** and comparable activity to acarbose, an antidiabetic drug. Finally, three preussin probes (**TP8, TP10,** and **TP11**) decreased FL-micelle cholesterol transport in a similar degree with compound **3** and ezetimibe, indicating that they did not interfere with a high potency of lipid-lowering activity of compound **3**. Identification of targets for **3**, its probe **TP8**, and ezetimibe using chemical proteomic approaches revealed that 33 differentially expressed proteins were significant among the 4 groups (control, **TP8**-, **3**-, and ezetimibe-treated Caco-2 cells).

Conclusion: Based on the above results, preussin (**3**) and **TP5** are a potential lead candidate for development as cholesterol absorption inhibitor whereas **TP1** and **TP2** could be potential candidates for obesity and diabetic drug discovery. Additionally, **probe 1-4, probe 2-1**, three probes of compound **3** (**TP8**, **TP10** and **TP11**) and probe of **TP5** (**TP9**) will be employed for the identification of protein targets using proteomic approach.

Current Output: 3 publications: Pharmaceuticals, 2022, 15, 955; PLoS Negl Trop Dis, 2022, 16(12), e0010989; Bioorg Med Chem Lett, 2023, 93, 129437.

Challenges/Problems and Possible solutions (if any): none

Future plan: The research will involve evaluation of anti-diarrheal effect of the statin **2** and **probe 2-1** using human enteroid models, verification of the cholesterol absorption activity

of **TP9** and identification of targets for **probe 1-4, probe 2-1**, and **TP8-TP10** using chemical proteomic approaches.

Rational Design of Composite for Novel Implementation of Nanoparticles Derived from Natural Rubber, Magnetic and Advanced Metal Oxide for Environmental and Health Applications in Sustainable Ways

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 70%

Abstract:
Besides fabrication of hollow magnetic polyaniline (HoM-PANI) nanoparticles (NPs) via oxidative polymerization for developing electromagnetic (EM)/ultraviolet (UV)-visible (Vis)-near infrared (NIR) shielding material, magnetic (Fe_3O_4), silver (Ag), bismuth oxyiodide (BiOI) and bismuth vanadate ($BiVO_4$) NPs for novel implementation were prepared. For microbial enrichment, surface of Fe_3O_4 NPs was modified with SiO_2 and 3-aminopropyl-triethoxysilane. Efficacy of these Fe_3O_4@SiO_2_NH_2 NPs for isolating *Leptospires* and influenza A/H1N1 was examined by varying incubation time, particle/microbial concentration. Within 2 and 15 min, the particles can effectively bind to *Leptospires* and influenza A/H1N1 via physical interaction. In parallel, the antimicrobial properties of natural rubber (NR) film were generated and enhanced by spraying AgNPs having chitosan (CS) as reducing and stabilizing agent on the surface of pre-stretched rubber. Surface roughness of the coated films increased from 18 – 64 nm, when increasing elongation during spraying. The synthesized BiOI, $BiVO_4$, and their degradation efficiency under visible light were also investigated.

Rationales/Problem statements:
To create new knowledge in surface chemistry and colloids, the advanced composite NPs containing natural polymers, e.g., NR and CS, and/or inorganic substances, e.g., Fe_3O_4, Bi, SiO_2, and Ag, were tailored for health and environmental applications.

Objectives:
1. To synthesize double-shell hollow composite particles composed of natural polymers and/or conductive polymers containing ZnO or magnetic (M) NPs using one-pot process.
2. To fabricate MNPs for enrichment of SARS-CoV-2 for immunology research and vaccine production.
3. To synthesize BiOI onto both hollow and solid SiO_2 NPs and study the mechanism of the composite particle formation.
4. To develop an efficient and easy pre-stretching/spraying technique for coating the composite particles on a rubber film and/or fibers or textiles.

Progress/Findings/Results:
1. HoM-PANI NPs with a large void size were effectively synthesized using poly(sodium 4-styrenesulfonate) (PSS) with M_w of 70K and 1 M as surfactive dopant. The particles

exhibited high shielding ability in UV-Vis-NIR region. The high EM interference (I) shielding of poly(vinyl alcohol) (PVA) composite film containing the HoM-PANI NPs was due to the increase in conductive path as well as the multiple reflections between void and polymeric shell of nearby hollow particles.

2. The synthesized Fe_3O_4@SiO_2_NH_2 NPs (particle size = 21.1 ± 3.4 nm, zeta potential = 2.8 ± 2.2 mV and saturated magnetization (Ms) = 28.1 ± 0.1 emu/g) were used as a nano-based tool for enrichment of *Leptospira* and influenza A/H1N1. Incubation time and microbial/particle concentrations were optimized to attain the maximum binding efficiency. Using these NPs functionalized with polyclonal antibody to *Leptospira*, the particles could capture the bacteria at a concentration as low as 10 cfu/mL within 2 min due to the surface-specific interaction. While binding efficiency > 99% was achieved within 15 min for pristine positively charged Fe_3O_4@SiO_2_NH_2 NPs to isolate influenza A/H1N1.

3. AgNPs coated with CS (AgNPs-CS) were synthesized using the autoclaved-assisted method. Their particle size could be controlled from 35 to 100 nm by adjusting the reaction time and amount of ascorbic acid. After spraying these NPs on the surface of pre-stretched NR film, atomic force microscopy (AFM) showed that the surface roughness increased with increasing the elongation of NR film from 18 nm for uncoated, 38 nm for non-stretched to 64 nm for stretched NR film at 200%elongation.

4. For the formation of BiOI-coated SiO_2 (SiO_2@BiOI), both pH and SiO_2:Bi ratio does not affiliate the growth of BiOI on the surface of SiO_2 NPs. Instead, BiOI seemed to freely grow as plate or sheet at low Bi concentration. Increasing Bi concentration induced the assembly of BiOI sheet to 3D-flower-like structure. Band gap energy of resulting SiO_2@BiOI was close to that of BiOI. The degradation ability of SiO_2@BiOI in PVA film under visible light, evaluated using methylene blue (MB) as a model organic pollutant, showed the maximum degradation of ca. 15%.

Conclusion:

1. Large void and high electrical properties of HoM-PANI NPs were achieved using PSS. PVA film having these NPs exhibited high UV-Vis-NIR and EMI shielding efficiency.
2. Under optimized incubation time and particle concentration, the Fe_3O_4@SiO_2_NH_2 could effectively bind to *Leptospira* and influenza A/H1N1.
3. Spraying/stretching technique was simple and efficient for fabricating antibacterial NR film. Surface roughness could be tuned by varying the elongation of film.
4. Factors affecting the formation of SiO_2@BiOI, pH and precursor ratio were investigated. Under visible light, the maximum degradation of MB was ca. 15%.

Current Output: 4 International publications

1. Kaewsaneha C, Thananukul K, Opaprakasit P, Tangboriboonrat P, Sreearunothai P, ***Progress in Organic Coatings***, 2022;173;107173 (Q1, IF 6.206).
2. Teawprasong P, Wongngam Y, Tangchaikeeree T, Elaissari A, Tangboriboonrat P, Polpanich D, Jangpatarapongsa K, ***Scientific Reports***, 2022;12;20677 (Q1, IF 4.996).
3. Kraithep C, Sajomsang W, Minami H, Busabok C, Tangboriboonrat P, Chaiyasat P, Chaiyasat A, ***Surfaces and Interfaces***, 2023;37;102738 (Q1, IF 6.2).
4. Promlok D, Wichaita W, Phongtamrug S, Kaewsaneha C, Sreearunothai P, Suteewong T, Tangboriboonrat P, ***Progress in Organic Coatings***, 2024; 186;108002 (Q1, IF 6.6).

Future plan:

1. Optimization of whole cell/RNA virus isolation and prototype development
2. Investigate the effect of surface roughness of AgNPs-CS coated NR film on antibacterial properties.
3. Optimization of photocatalysis degradation of SiO_2@BiOI and preparation method

Study and Development of Porous Coordination Polymers for Electrocatalytic Applications

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Project duration: 1 year, from 21 September 2022 to 20 September 2023

Current progress: 80%

Abstract: The electrocatalytic performance of the highly robust Co-trz was targeted for improvement through two approaches: mixed-metal and ligand functionalization. Accordingly, two structures, CoNi-Trz and Co-Trz-NH_2, were synthesized. The electrocatalytic performance for the oxygen evolution reaction (OER) of the mixed metal CoNi-Trz structure significantly improved, providing a lower overpotential of 293 mV measured at 10 mA cm^{-2}, compared with the pristine Co-Trz (345 mV). This is due to the alteration of the framework due to the present of Ni. On the other hand, Co-Trz-NH_2, obtained from the -NH_2 functionalized triazolate ligand, did not show improved electrocatalytic activity. However, Co-Trz-NH_2 can be utilized in photocatalytic hydrogen production. In a catalytic system including fluorescein and triethylamine as photosensitizer and hole scavenger, respectively, 27 mmol H_2/g MOF can be produced in 4 hours.

Rationales/Problem statements: It is known that the electronic structures, which subsequently affect the catalytic performance of inorganic electrocatalysts, can be altered by doping with 2nd or 3rd metals. On the other hand, since MOFs are composed of metal and ligand, functional groups on the ligand should also contribute to changing the electronic structure of the entire framework. These concepts can be implemented to enhance the efficiency of MOF electrocatalysts. As recently reported by our group, Co-Trz could be employed as an efficient electrocatalyst for the OER. The framework is constructed from Co^{2+} in a half-octahedral and half-tetrahedral geometry, along with a 1,2,4-triazole ligand. Ni was considered as a 2nd metal to be added in the structure since

Objectives: This project focuses on the study and development of metal-organic frameworks (MOFs) also known as porous coordination polymers (PCP) for use as highly efficient electrochemical catalysts, which can be further applied to improve the efficiency of rechargeable batteries and is highly environmentally friendly. Based on the previous studied, Co-trz was demonstrated as an efficient catalyst for oxygen evolution reaction (OER). Herein, two strategies, i.e., mixed-metal and ligand functionalization were studied to improve its catalytic performance.

Progress/Findings/Results: CoNi-trz was synthesized using a microwave-assisted hydrothermal method, resulting in a crystallized rod morphology with a nano-scale diameter. Ni ions coordinated with six trz molecules in an octahedral geometry, forming a 1D skeleton of the framework. Co ions were in tetrahedral geometry, coordinating with three trz and one Cl anion. The electrocatalytic performance for OER of the mixed-metal CoNi-Trz was examined in O2-saturated 1 M KOH using the standard three-electrode system. Platinum rod, Hg/HgO, and CoNi-Tz were employed as counter, reference, and working electrodes, respectively. The reactivity was found to be improved compared with pristine Co-Trz. The overpotential at the working current density of 10 mA cm^{-2} (η_{10}) for Co/Ni–trz was only 293 mV, lower than that of Co-Trz (345 mV). CoNi-trz was identified as a pre-catalyst. The

framework underwent reconstruction under electrochemical reaction conditions, forming reactive mixed-metal CoNi oxide/hydroxide. Additionally, to reach maximum reactivity, more than 100 cycles were required, emphasizing the evaluation of catalytic sites during electrocatalytic activation. The mixed CoNi-trz was not as robust as the pristine Co-trz, which can catalyze the reaction without changing to an oxide/hydroxide form. This is attributed to the different 1D chain skeleton, responsible for maintaining the framework structure. Under the reaction conditions, the octahedral Co-chain is more stable than the Ni-chain.

Co-trz-NH_2 was obtained using a microwave-assisted hydrothermal method. However, this compound does not exhibit any improvement in catalytic reactivity for OER. The photocatalytic reactivity of this compound for H_2 production from water splitting reactions was examined. High H_2 production of about 25 mmol g^{-1} in 4 hours (production rate of 6.7 mmol g^{-1} h^{-1}, calculated by excluding the induction time) was achieved using fluorescein (FI) as a photosensitizer and triethylamine (TEA) as a sacrificial agent. Due to the framework's robustness, its structural integrity and catalytic reactivity remained unaffected even after the reaction. Under similar conditions, the catalytic activity was much better than that of pristine Co-trz (9.2 mmol g^{-1} in 4 hours). The functional -NH_2 group with an electron-donating attribute altered the electronic property of the framework, enhancing the photocatalytic reaction. It facilitates the travel of the photoexcited electron received from the photosensitizer Fl to occur the hydrogen evolution reaction on the tetrahedral active sites throughout the framework.

Conclusion: The electronic structures of Co-based frameworks were engineered using mixed-metal and ligand functionalization approaches. The mixed metal CoNi-trz, acting as a precatalyst, transformed into the active species CoNi oxide/hydroxide, exhibiting excellent OER electrocatalytic performance with a low overpotential of only 293 mV at the working current density of 10 mA cm^{-2} (η_{10}). On the other hand, Co-trz-NH_2, synthesized with the -NH_2 functionalized triazole ligand, exhibited significant reactivity in photocatalytic H_2 production, reaching 9.2 mmol g^{-1} in 4 hours. The reaction system required fluorescein (FI) as a photosensitizer and triethylamine (TEA) as a sacrificial agent.

Current Output: 2 manuscripts in preparation

Challenges/Problems and Possible solutions: No

Future plan: The photocatalytic reactivity of Co-trz-NH_2 is impressive compared with other typical semiconductor photocatalysts. However, in our case, a sensitizer is needed to harvest light in visible regions. There is potential to design the framework to perform without the presence of the sensitizer, aiming to enhance efficiency, reduce costs, simplify processes, improve stability, and broaden the scope of applications in various fields, including environmental remediation, energy conversion, and the synthesis of valuable compounds.

Novel MXenes Based Materials and Their Composites for Energy and Sensor Applications

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Project duration: 3 year, from 1 November 2021 to 31 October 2024
Current progress: 70%

Abstract:
MXene, such as $Ti_3C_2T_x$, fabricated by wet chemical etching possesses plenty of active terminal groups (e.g., F, O, and OH) on its surface, which may interact with polymers by hydrogen bonding to make up for the low mechanical strength of the pure MXene material. In this work, we proposed the alloying and composition design strategy to control of properties of two-dimensional transition metal carbides known as MXenes and/or cellulose nanofibers (CNF)-based materials/composites, a following heat treatment process will be also applied to further enhance the properties. The MXenes/CNF-based composites will be developed for energy storage and sensor applications.

Rationales/Problem statements:
No, we will complete all our proposed activities.

Objectives:
1. To prepare the novel MXenes, MXenes/CNFs, MXenes/CNFs-based and MXenes/CNFs-derived composite via a facile room-temperature approach and following annealing process.
2. To optimize the content of MXenes, CNF, metal oxides/sulfides/layer double oxides, and fabrication conditions that produce a high performance of energy storage and sensor electrode.
3. To understand the possible mechanism for the enhanced energy storage properties and sensor performances of MXenes, MXenes/CNF-based nanocomposites

Progress/Findings/Results:

(1) Through SPS sintering and etching, we successfully synthesized $Ti_2NbC_2T_x$ with a unique accordion-like lamellar structure. After doping with Nb element, the sample obtained a larger interplanar spacing, and improved the transport rate of Li^+ ions and the infiltration capacity of the electrolyte.

(2) A nanohybrid structured electrode composed of Nb-TiO_{2-x} outer layer conformally coated on a conductive $(Ti_{0.9}Nb_{0.1})_3C_2T_x$ MXene core (Nb-TiO_{2-x}/MXene) have been fabricated via a spark plasma sintering, etching, and vacuum annealing method.

(3) The bulk Ti_3C_2 MXene was also obtained through the etching method by the mixed solution containing 1.5 g LiF and 15 mL 6 M HCl, then NiMn LDH was grown/deposited on as-prepared single-layer MXene via an in situ crystallization strategy.

(4) The NiMn-LDH-derived Ni-doped Mn_2O_3 was synthesized and can deliver high specific capacity and excellent cycle performance as cathode for ZIBs.

(5) $Ti_3C_2T_x$ Mxene composite electrospun fiber mats were successfully fabricated with up to 10wt% of $Ti_3C_2T_x$ Mxene. The obtained PAN/bio-based PU/$Ti_3C_2T_x$ Mxene can be applied for Zn ion battery separators.

(6) ZrO_2-cellulose composite separator prepared via a facile and cost-effective approach towards dendrite-free and extremely durable zinc anode. The rate capacities and cyclic stability of Zn||$ZnSO_4$||MnO_2/graphite full cell are greatly improved via the ZC separator due

to the enhanced ionic conductivity and reaction kinetics. In particular, the pouch cell with ZC separator delivers remarkable flexibility and satisfactory integration ability. Compared with other commercial separator (glass fiber) and reported zinc anode protection strategies, the ceramic-cellulose based separator employed in this research is much simple and cost-efficient, which offers a novel perspective to engineer a dendrites-free zinc anode and brings more possibilities for the next-generation metal anode-based devices.

(7) WC-cellulose separator with the features of high mechanical strength and low cost were prepared via facile solution-casting method for stable and high-performance AZIBs. The prepared WCCNF separator can effectively reduce Zn nucleation overpotential, inhibit surface corrosion and passivation, and promote reversible Zn plating/stripping. As a result, the assembled Zn||NVO pouch cell using WCCNF also produces a high discharge capacity of 121.6 $mAh \cdot g^{-1}$ with a high capacity retention of 84.4% after 50 cycles at 0.5 $A \cdot g^{-1}$. Therefore, the prepared WC-cellulose separator with low cost and high efficiency for dendrite-free and stable Zn anode provides a promising separator candidate in the large-scale commercialization of high-performance AZIBs.

(8) Non-enzymatic electrochemical sensor based on MXene/CuO/PEDOT:PSS modified screen-printed electrode was successfully created for the urea detection. MXene supported CuO were synthesized though a thermal decomposition method and it were incorporated with PEDOT:PSS for enhance the high surface area , electroconductivity, and electrocatalytic properties for urea detection.

(9) The DPV measurement was performed to study the electrochemical sensing performance of the AgNPs/Mxene nanocomposite modified on SPGE compared with the unmodified electrode and Mxene modified on SPGE, the carbaryl detection performance of AgNPs/Mxene nanocomposite modified on SPGE, the DPV response showed an increased carbaryl peak upon increasing carbaryl concentration, and AgNPs/MXene nanocomposite electrodes were used to determine CBR in orange sample to evaluate the applicability of this platform.

Conclusion:

In conclusion, we developed the alloying and composition design strategy to control of properties of $Ti_3C_2T_x$, $(Ti_{0.9}Nb_{0.1})_3C_2T_x$, Ti_3C_2 MXene hybrid with NiMn-LDH and/or cellulose nanofibers (CNF)-based materials/composites (CNF-ZrO_2 and CNF-WC composite membranes for separators), a following heat treatment process will be also applied to further enhance the properties (Nb-TiO_{2-x}/MXene and Ni-doped Mn_2O_3). Furthermore, MXene/CuO/PEDOT:PSS modified screen-printed electrode and AgNPs/Mxene nanocomposite modified on SPGE were also developed in this project for urea and carbaryl detection.

Current Output:

1. B.S. Reghunath, S. Rajasekaran, K.R. Sunaja Devi, B. Saravanakumar, J. Johnson William, D. Pinheiro, D. Govindarajan, S. Kheawhom, Fabrication of bismuth ferrite/graphitic carbon nitride/N-doped graphene quantum dots composite for high performance supercapacitors, Journal of Physics and Chemistry of Solids 171 (2022) 110985. (Q1 in Scopus)
2. W. Niamsi, N. Larpant, P. K. Lalambate, V. Primpray, C. Karuwan, N. Rodthongkum, W. Laiwattanapaisal, Paper-based screen-printed ionic-liquid/graphene electrode integrated with PB/Mxene nanocomposites enable electrochemical detection for glucose sensing, Biosensors, 12 (2022) 852. (Q1 in Scopus)
3. T. Chen, C. Yang, S. Rajendran, M. Sawangphruk, X. Zhang, J. Qin, Utilizing the built-in electric field of p-n heterojunction to spatially separate the photogenerated

charges in C, N co-doped CO3O4/CdS photocatalysts, Fuel 331 (2023), 125594. (Q1 in ISI)
4. R. Venkatkarthick, J. Qin, T. Maiyalagan, Amorphous cobalt boride nanoparticles incorporated vanadium carbide Mxene composite for asymmetric supercapacitor applications, International Journal of Energy Research (2022) 1-12 (T1 in Scopus).
5. D. Govindarajan, N. Palaniyandy, K.K. Chinnakutti, M.T. Nguyen, T. Yonezawa, J. Qin, S. Kheawhom, Sputter-deposited binder free nanopyramidal Cr/Y-Mo2N TFEs for high-performance supercapacitors, Nanoscale Research Letters, 17 (2022), 65. (T1 in Scopus)
6. S. Saisangtham, C. Likitaporn, P. Kasemsiri, J. Qin, M. Okhawilai, P. Potiyaraj, H. Uyama, Polyacrylonitrile/bio-based polyurethane electrospun fiber mats as advanced separators for high-performance Zn-ion batteries, Express Polymer Letters, 8 (2022) 827-845 (Q1 in Scopus).
7. Z. Dai, J. Cao, F. Song, D. Zhang, J. Qin, X. Zhang, Architecting Nb-TiO2-x/(Ti0.9Nb0.1)3C2Tx Mxene nanohybrid anode for high-performance lithium ion batteries, Advanced Materials Interfaces 9 (2022), 2101658 (T1 in Scopus)
8. R. Venkatkarthick, J. Qin, T. Maiyalagan, Amorphous cobalt boride nanoparticles incorporated vanadium carbide Mxene composite for asymmetric supercapacitor applications, International Journal of Energy Research (2022) 1-12 (T1 in Scopus)
9. D. Govindarajan, N. Palaniyandy, K.K. Chinnakutti, M.T. Nguyen, T. Yonezawa, J. Qin, S. Kheawhom, Sputter-deposited binder free nanopyramidal Cr/Y-Mo2N TFEs for high-performance supercapacitors, Nanoscale Research Letters, 17 (2022), 65. (T1 in Scopus)
10. S. Saisangtham, C. Likitaporn, P. Kasemsiri, J. Qin, M. Okhawilai, P. Potiyaraj, H. Uyama, Polyacrylonitrile/bio-based polyurethane electrospun fiber mats as advanced separators for high-performance Zn-ion batteries, Express Polymer Letters, 8 (2022) 827-845 (Q1 in Scopus)
11. C. Likitaporn, M. Okhawilai, P. Kasemsiri, J. Qin, P. Potiyaraj, H. Uyama, High electrolyte uptake of Mxene integrated membrane separators for Zn-ion batteries, submitted to Journal of Science: Advanced Materials and Devices (T1 in Scopus)
12. C. Yang, Y. Chen, T. Chen, J. Low, S. Rajendran, Z. Zeng, X, Zhang, J. Qin “Active site modulation of porous g-C3N4 nanofragment via defect assemblage for enhancing visible-light driven hydrogen evolution” Fuel, 337, 2023, 126894.
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17. P. Kantichaimongkol, J. Cao, D. Zhang, Z. Zeng, X. Zhang, J. Qin “Navajoite phase V5O12•6H2O nanorods with ultra−long lifespan for aqueous zinc−ion batteries” Journal of Alloys and Compounds 937, 2023, 168335.

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20. Z. Dai, K. Rajendran, J. Cao, D. Zhang, R. Chanajaree, C. Yang, P. Tan, X. Zhang, J. Qin. “Low-cost electrolyte additive enables an ultra-stable and dendrite free Zn anode” Energy Fuels, 2023, 37, 13536-13545.
21. P. Woottapanit, C. Yang, J. Cao, W. Limphirat, S.na ayuttaya, X. Zhang, P. Wangyao, J. Qin. “Inhibition of zinc dendrite growth by WC-cellulose separators for high performance zinc ion batteries” ACS Applied Energy Materials, 2023, 6, 10578-10584.

Challenges/Problems and Possible solutions: No

Future plan:

1. Design and preparation of the in situ optical microscope study setup
2. In situ optical microscope study of battery anode and cathode during the charging/discharging
3. Design and preparation of the in situ Raman spectroscopy setup
4. In situ Raman spectroscopy study of battery anode and cathode during charging and discharging
5. Integrated the battery and sensor device
6. Evaluation of the integrated device performance with our developed battery and sensor electrodes

Novel Printed 2D Materials Based Electrochemical MicroRNA Biomarker Sensor for Cancer Detection in Liquid Biopsy

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 75%

Abstract:

In this work, a screen-printed electrode consisting of two-dimensional materials, including reduced graphene oxide (rGO) and molybdenum disulfide (MoS_2), was firstly developed as screen-printed rGO-MoS_2 electrode (SPrGO-MoS_2E) to be coupled with gold nanoparticles (AuNPs) and potassium ferricyanide ($K_3[Fe(CN)_6]$) redox probe for microRNA (miRNA) detection which is a biomarker in cancer patients using the developed portable electrochemical device. Overall, this work confirmed the excellent performance of developed portable electrochemical prototype which will be applied for miRNA detection in real samples.

Rationales/Problem statements:

Generally, the analysis of miRNA in secretion (blood, urine, etc.) is performed by relying on enzyme-linked immunosorbent assay (ELISA). However, ELISA has a limitation because it is laborious for preparing antibody and inconvenient for on-site application. Thus, the monitoring of miRNA using biopsy has been developed because blood samples could be easily collected, and the patients are not hurt and has high safety. Therefore, this research work will overcome limitations of ELISA using biopsy and portable electrochemical device consisting of SPrGO-MoS_2E, AuNPs, and K_3FeCN_6 redox probe to determine miRNA in cancer patients.

Objectives:

1. To develop disposable sensors from two-dimensional conductive materials such as Graphene Mxene or TMDCs with screen printing technology to achieve highly sensitive and affordable cost sensors.
2. To develop a method for measuring and analyzing miRNA cancer markers. Using the patient's serum (Liquid biopsy) using a specific electrochemical technique using genetic material. complementary deoxyribonucleic acid (cDNA) to be used as a model for the analysis of tumor markers, type of RNA. or follow up on treatment and test the effectiveness of the developed method in analyzing real blood samples compared with standard methods.
3. To develop a portable electrochemical reader and connection system for collecting measurement data using internet of things technology.
4. To apply the above method to patient blood samples and compare the results with standard methods.

Progress/Findings/Results:

For a developed portable device, the electrochemical response of 5 mM K_3FeCN_6 solution in the presence of miRNA using cyclic voltammetry (CV) was shown in Fig.1(a).

It was found that the K_3FeCN_6 current decreased such as 83.3 µA, 98.5 µA, 103.5 µA, 120.0 µA and 138.8 µA, respectively as higher concentrations of miRNA. The correlation coefficient (r^2) was equal to 0.969, which confirmed the miRNA detection efficiency of the developed analysis kit as presented in Fig. 1.

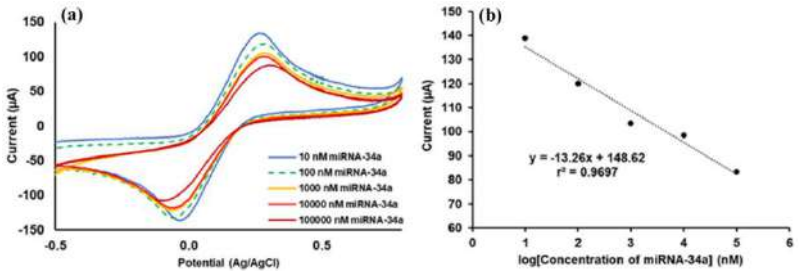

Fig. 1 Cyclic voltammogram (CV) and (b) linear graph showing the relationship between the anodic current of 2.5 mM K_3FeCN_6 solution and miRNA34a concentration analyzed using the developed portable electrochemical device.

Conclusion

Overall, the electrochemical detection performance of miRNA tested by the developed portable electrochemical device gave the anodic current that was related with miRNA concentration. Therefore, it is possible to further develop portable electrochemical device in various modes for testing with miRNA in real samples.

Current Output:

1. **A prototype**: A disposable screen-printed electrode containing two dimensional materials
2. **A prototype:** A prototype of a portable electrochemical reader
3. **Three published international journals**

- Paper-Based Screen-Printed Ionic-Liquid/Graphene Electrode Integrated with Prussian Blue/MXene Nanocomposites Enabled Electrochemical Detection for Glucose Sensing, Biosensors 2022, 12(10), 852.
- Highly sensitive and disposable screen-printed ionic liquid/graphene based electrochemical sensors, Electrochemistry Communications 2022, 135, 107209.
- Simultaneous electrochemical sensing of Cd^{2+} and Pb^{2+} using screen-printed ionic liquid/graphene electrodes, International Journal of Environmental Analytical Chemistry, https://doi.org/10.1080/03067319.2023.2246904

4. **A petty patent filed: Topic:** Conductive carbon ink containing two-dimensional (2D) reduced graphene oxide/molybdenum disulfide composite (Filed date: 27/09/2023, Appl. No. 2303002799)
5. **A patent:** There is a work which is in the process of applying for a patent.

Topic: Electrochemical detection of miRNA 34a as a cancer biomarker using screen-printed reduced graphene oxide and molybdenum disulfide electrode modified with gold nanoparticles

Challenges/Problems and Possible solutions:

All of research plans were achieved within time period and problems could be overcome.

Future plan:

1. To analyze the amount of miRNA in patient serum (Liquid biopsy) using the developed portable electrochemical device with designed specificity using genetic material of complementary deoxyribonucleic acid (cDNA)
2. To develop a portable electrochemical device and connection system for collecting measurement data using Internet of Things technology.

Development of High Performance Glass Fiber Post Based on a Novel Type of Phenolic Resin: Petroleum-based Polybenzoxazine, Bio-based Polybenzoxazine, and Bio-based Polybenzoxazine Copolymers

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Project duration: 3 years, from 1 November 2021 to 1 October 2024

Current progress: 65.7%

Abstract:

Glass fiber-reinforced polybenzoxazine composites were developed to act as a new dental fiber post. Chemical characteristics, mechanical, thermal, and biological properties of the polybenzoxazine composites at various glass fiber contents have been studied. The mechanical response of the tooth model restored with the polybenzoxazine composite posts was also analyzed and compared against a natural healthy tooth model. Flexural property, thermal expansion, and thermal stability of the polybenzoxazine composites were significantly enhanced with the introduction of reinforcing glass fiber into polybenzoxazine. The developed composites proved to be cytocompatible materials. Stress distribution by finite element analysis of the tooth model restored with the polybenzoxazine composite post showed that higher glass fiber content tended to reduce stress values in dentin. Therefore, the glass fiber-reinforced polybenzoxazine composites show good promise as biocompatible dental materials with good mechanical behavior and thermal properties.

Rationales/Problem statements: -

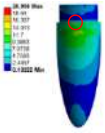
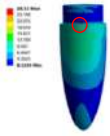
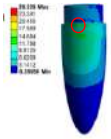
Objectives:

1. To develop glass fiber post from polybenzoxazine (petroleum and bio-based polybenzoxazine) reinforced with glass fiber.
2. To study effects of glass fiber contents on mechanical, thermal, and important physical properties of the glass fiber posts.
3. To evaluate mechanical response by finite element analysis of tooth model restored with obtained glass fiber post and compared with tooth model restored with commercial posts and healthy natural tooth.

Progress/Findings/Results:

Glass fiber (GF) posts made from a matrix of petro-polybenzoxazine (BA-a), bio-polybenzoxaizne (E-fa) and bio-polybenzoxazine/epoxy (E-fa/ECO) have been developed. The mechanical, thermal, and biological properties of the obtained glass fiber posts was evaluated. The possibility of using obtained glass fiber posts to restore tooth model by finite element analysis (FEA) was also studied and compared with the tooth model restored with commercial glass fiber post and healthy natural tooth model. The properties of the obtained GF posts are summarized and listed in Tables 1.

Table 1 Properties of obtained glass fiber posts.

Property	**80 wt% GF/ BA-a post**	**70 wt% GF/ E-fa posts**	**Commercial GF post** [1]	**Healthy natural tooth (dentin)**
Flexural modulus (GPa)	28.0	18.3	37	18.6-40 [2,3]
CTE @ 20-50 ^{o}C (ppm/^{o}C)	12.8	0.03	na	8.3-11.4 [4]
Degradation temp. at 5% weight loss (^{o}C)	391	374	na	~100 [5]
Biological property	Biocompatible material	na	na	
FEA: max. von Mises stress (GPa)	20.954 	in progress	28.320 	26.226 

[1] Coelho C, Biffi J, Silva G, Abrahao A, Campos R, Soares C (2009) Finite element analysis of weakened roots restored with composite resin and posts. Dent Mater J 28:671-678.
[2] Bateman G, Ricketts DN, Saunders WP (2003) Fibre-based post systems: A review. Br Dent J 195:43-48.
[3] Novais VR, Quagliatto PS, Bona AD, Correr-Sobrinho L, Soares CJ (2009) Flexural modulus, flexural strength, and stiffness of fiber-reinforced posts. Indian J Dent Res 20:277-281.
[4] Hengchang X, Wenyi L, Tong W (1989) Measurement of thermal expansion coefficient of human teeth. Aust Dent J 34:530-535.
[5] Vargas-Becerril N, García-García R, Reyes-Gasga J (2018) Structural changes in human teeth after heating up to 1200°C in argon atmosphere. Mater Sci Appl, 9:37-656.

Conclusion:

Glass fiber-reinforced polybenzoxazine composite posts showed good performance to be used dental fiber post as follows: (1) Elastic modulus of the posts was similar to that of dentin which reduced the risk of root failure (2) Its thermal expansion tended to reach the CTE of dentin and (3) The developed post proved to be cytocompatible materials that possess satisfactory biological property. Based on the findings in this study, it is evident that the posts have great potential and prospect in dental applications**.**

Current Output:

1. Mora, P.; Nunwong, C.; Sriromreun, P.; Kaewsriprom, P.; Srisorrachatr, U.; Rimdusit, S.; Jubsilp, C. High performance composites based on highly filled glass fiber-reinforced polybenzoxazine for post application. Polymers 2022, 14, 4321 (Scopus, Q1)
2. Chumjitr, K.; Tumpanitsakul, T.; Sukvaree, T.; Mora, P.; Rimdusit, R.; Jubsilp, C. Mechanical and thermal property of glass fiber-reinforced biopolybenzoxazine composites, TIChE2023, Nakhon Pathom, Thailand, March 16-17, 2023
3. Mahawan, A.; Singhor, A.; Danamkam, K.; Jubsilp, C.; Mora, P.; Improvement of mechanical and thermal properties of bio-based polybenzoxazine/epoxy composites reinforced with glass fiber, TIChE2023, Nakhon Pathom, Thailand, March 16-17, 2023
4. Mora, P.; Rimdusit, S.; Karagiannidis, P.; Srisorrchatr, U.; Jubsilp, C., Biocompatible glass fiber-reinforced polybenzoxazine composites as a potential new endodontic post. (under consideration for Bioresources and Bioprocessing (submission ID: BIOB-D-23-00194), Scopus: Q1)
5. Pending-Thailand Patent No. 2301004009, Dental post from polymer composites reinforced with fibers, 27 June 2020
6. One prototype of glass fiber post from glass fiber-reinforced poly(BA-a) composite

Challenges/Problems and Possible solutions (if any): -

Future plan:

- To study effects of glass fiber contents of glass fiber posts based on polybenzoxazine/epoxy biocopolymer on essential property for safer and eco-friendly dental fiber post.
- To prepare three manuscripts for submission in international journal.
- To prepare abstract and extended abstract to submit the academic international conference.

Application of Intensification Reactor for Conversion of Glycerol to Produce Mono- and Di-glycerides

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 70%

Abstract:

This research focuses on glycerol valorization to produce MG and DG. Various feedstocks, catalyst type and intensification reactors were considered. A continuous spinning disc reactor (C-SPR) gave a high TG conversion of 90% and S_{MG} of 64% at the reaction temperature 200 ^{o}C, a NaOH loading of 0.3 wt.%, a glycerol to palm oil molar ratio of 3:1, a total volumetric flow rate of 100 mL/min, and a rotational disc speed 1,000 rpm. Whereas, oleic conversion of 91.1%, monoolein yield of 36.1% and mixture of monoolein and diolein yield of 85.5% at 2 h were accomplished using a modified fruit blender reactor (M-FBR) at a stirring speed of 3,170 rpm, a glycerol to oleic molar ratio of 2.97 to 1 and a MSA loading of 2.77%. All glycerolysis routes with various substances (TG, FFA, and biodiesel) and catalyst type (heterogeneous catalyst and enzyme) as well as techno-economic analysis will be further explored to complete overview of glycerol valorization.

Rationales/Problem statements:

Recently, a huge amount of crude glycerol is generated from biodiesel production industry, resulting in a gradual drop for the glycerol price over the years. Consequently, the conversion of glycerol to bio-based commodity products has been emphasized. Glycerolysis of crude glycerol is an interesting glycerol usage to produce monoglyceride (MG) and diglyceride (DG) as emulsifying agent for food and cosmetic industry which can raise the value of crude

glycerol. However, the mass transfer limitation of non-soluble glycerol and oils (triglyceride (TG) and free fatty acids (FFA)) and its reversible nature are major obstacles. The intensification reactors including C-SDR and M-FBR have been proposed to overcome this barrier. Since, these reactors provide the effective mixing by shear and centrifugal force as well as cavitation phenomena to increase interfacial area of non-soluble reactant resulting to diminish the slow step mass transfer.

Objectives:

To develop intensification reactors for glycerol valorization to produce MG and DG including of glycerolysis of palm oil using C-SDR and glycerolysis of FFA using M-FBR. The important operating parameters including oil/FFA to glycerol molar ratio, reaction temperature and catalyst loading to achieve the optimum conditions for high MG and DG yield were investigated. To grasp the glycerol valorization overview, all glycerolysis routes with various substances (TG, FFA and biodiesel) and catalyst type (heterogeneous catalyst and enzyme) will be further explored. This information will be used for MG and DG production from crude glycerol plant simulation providing more feasibility both techno-economic and environmental impact.

Progress/Findings/Results:

Two intensification reactors for MG and DG production from glycerol were developed. The C-SDR has high shear mixing with a good mass transfer performance. The homogeneous catalyst of NaOH was used in the glycerolysis of palm oil. The reaction was performed with a glycerol to palm oil molar ratio of 2:1, a total volumetric flow rate of 100 mL/min, reaction temperatures of 140 to 200^{o}C, and a NaOH loading of 0.1 to 0.3 wt.% of palm oil. It was found that the increase reaction temperature gave rising to the TG conversion as well as the MG selectivity (S_{MG}). The TG conversion and the S_{MG} with increasing the NaOH loading have a similar trend with the effect of the reaction temperature. On the other hand, the rotational speed had a counterbalance effect on the TG conversion and S_{MG}. The TG conversion and the S_{MG} was lower when increasing the rotational speed because of the contacting time of the reactants was reduced at high rotational speed. Therefore, the optimal condition of the glycerolysis of palm oil should be operated with the reaction temperature greater than 200 ^{o}C, the NaOH loading of 0.3 wt.%, the glycerol to palm oil molar ratio of 3:1, the total volumetric flow rate of 100 mL/min, and the rotational disc speed lower than 1,500 rpm to provide the high TG conversion of 90%, S_{MG} of 64%, and yield efficiency of 47.04×10^{-5} g/J.

Furthermore, the M-FBR was used to produce monoolein and diolein via glycerolysis of oleic acid, hence this reactor provided the turbulence mixing as well as cavitation as derived from high stirring speed. The operation parameters involving stirring speed (1,800-3,600 rpm), MSA loading (0.32-3.68 wt.%) and glycerol to oleic acid molar ratio (0.32-3.68) investigated based on the center composite (CCD) and response surface methodology (RSM) to provide the interaction of each parameters and optimum operating condition. The reaction temperature and volume were fixed at 110 ^{o}C and 800 mL, respectively. The results showed that the glycerol to oleic acid molar ratio and methane sulfonic acid (MSA) loading were have significant influence on the glycerolysis, while less significant effect of stirring speed was observed. This could be due to the selected stirring speed provided the high turbulence mixing efficiency to overcome mass transfer limitation. The optimum condition was a stirring speed of 3,170 rpm, a glycerol to oleic molar ratio of 2.97 to 1 and a MSA loading of 2.77% resulting in oleic conversion of 91.1%, monoolein yield of 36.1 and mixture of monoolein and diolein yield of 85.5% at 2 h with higher yield efficiency of 8.880×10^{-5} g/J as compared to the conventional batch reactor (7.456×10^{-5} g/J). This optimum condition was further used to investigate the kinetic parameters for glycerolysis of oleic.

Conclusion:

This research shows the potential glycerol valorization to produce high value MG and DG emulsifies via glycerolysis using the intensification reactor. C-SPR can continuously produce MG and DG using total feed flowrate of 100 mL/min at 200 ^{o}C with high S_{MG} of 64% via glycerolysis of palm oil. When the substance was changed to FFA (oleic acid), the reaction temperature was reduced to 110 ^{o}C, providing high MG and DG yield of 85.5% but it required longer reaction time of 2 h in M-FBR. These 2 intensification reactors generate the effective mixing to overcome the insoluble glycerol and oils which is more potential for glycerolysis with various substance.

Current Output:

Publications (25 papers): 11 published papers in Tier 1, 4 papers under reviewed in Tier 1, 4 manuscripts under preparation to be submitted in Q1 and Tier 1 and 6 research experiments under investigated.

Prototypes (2 Intensification reactors) 1) Continuous spinning disc reactor (C-SDR)
2) Modified fruit blender reactor (M-FBR)

Challenges/Problems and Possible solutions:

The intermediate products (MG and DG) were firstly analyzed by following the ASTM6584 which required the derivatization. However, the substance and catalyst in the reaction mixture can interfere the derivative standard which could not generate the product peaks. Therefore, HPLC was used to track MG and DG peak which require the time for adjust the measuring condition to achieve high accuracy and reproduction.

Future plan:

The glycerolysis of biodiesel using heterogeneous catalyst and glycerolysis of FFA using enzyme will be further explored. This information will be used for the simulation of MG and DG production from crude glycerol plant providing more feasibility both techno-economic and environmental impact. In addition, the novel reactive distillation will be preliminarily simulated to shift the equilibrium forward to produce more MG and DG.

Research and Development of Nanoparticles Bone Cement for Bone Bonding in Medical Surgery

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 77%

Abstract:

The project proposes developing nanoparticle-compatible bone cement for bonding materials in medical applications. Bone cement from a combination of calcium phosphate and calcium sulfate was studied in vitro. It was found to have mechanical and setting properties that would be suitable for use as a bone cement. It is postulated that the hydrated calcium sulfate binder would provide adequate strength and be stable in the physiological environment, while the calcium phosphate aggregate would enhance the material's biocompatibility and lead to bioactivity. Physical properties such as phase composition, mechanical properties such as compressive strength, bonding strength between bone cement and animal cadaver bone/metal prosthesis, setting properties, tissue response to the bone cement, and the correlations between these characteristics will be mainly investigated.

Rationales/Problem statements:

Bone cement is used in orthopedic surgery to replace or bind bone fragments resulting from trauma, to fill cavities, or to secure an implanted prosthesis. Any enduring bone cement must be biocompatible, be stable in the physiological environment, and have adequate mechanical properties for stresses applied during daily activity. A few million patients per year need a biomaterial substitute to repair a bone defect resulting from an injury or a disease. Many biomaterial substitutes can be used: unprocessed or processed allogenic bone, animal-derived bone substitutes, and synthetic bone (biomaterial) substitutes, primarily ceramics. Ceramics have great potential in the biomedical field because of their biocompatibility, strength, and wear resistance. Its outstanding biocompatibility and excellent tribological properties allow alumina ceramics to be widely used in total joint prosthesis.

Objectives:

1. To characterize the nanoparticle of calcium phosphate from natural minerals.
2. To gain new knowledge and systematical understanding of developing new compatible bone cement made from a combination of calcium phosphate and calcium sulfate.
3. To investigate the physical properties such as phase composition, mechanical properties such as compressive strength, bonding strength between bone cement and animal cadaver bone /metal prosthesis, setting properties and tissue response to the bone cement in vivo of compatible bone cement made from a combination of calcium phosphate and calcium sulfate.
4. To produce the products from bone cement made from a combination of calcium phosphate and calcium sulfate in medical applications.

Progress/Findings/Results:

This project is focused on developing new compatible bone cement made from a combination of calcium phosphate and calcium sulfate, which is the nanoparticle of calcium

phosphate from a natural mineral. To investigate the physical change such as phase composition, mechanical properties such as compressive strength, bonding strength between bone cement and animal cadaver bone/metal prosthesis, setting properties, and tissue response to the bone cement *in vivo* of compatible bone cement made from a combination of calcium phosphate and calcium sulfate and produce the products from bone cement made from a combination of calcium phosphate and calcium sulfate in medical application.

Conclusion:

Current Output:

1. Pharatree Jaita, **Parkpoom Jarupoom***, Enhanced magnetic performance and in-vitro apatite-forming ability of the $CoFe_2O_4$ doped nano-hydroxyapatite porous bioceramics, *Microscopy Research and Technique*, 86, 2023, pp. 882-897. Q:1 (ISI, Scopus), IF: 2.893 (2023).
2. Pharatree Jaita, Komsanti Chokethawai, Chamnan Randorn, Kriangkrai Thongkorn, Kittikorn Boonsri, Kidsadagon Pringproa, Anucha Watcharapasorn, **Parkpoom Jarupoom***, Optimizing bioactivity and mechanical performances of advanced hydroxyapatite-calcium sulfate bone cement for bone regeneration: In-vivo histological study in rabbit femur, submitted, *Ceramics International*, Q:1 (ISI, Scopus), IF: 5.2 (2023)

Challenges/Problems and Possible solutions:

Future plan:

To investigate bonding strength between bone cement and animal cadaver, setting properties and tissue response to the bone cement.

Durability Properties of Novel Coating Material Produced by Alkali-Activated/Cement Powder

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[b] Department of Civil Engineering, School of Engineering, University of Phayao, Phayao 56000, Thailand
[c] Department of Survey Engineering, Faculty of Engineering and Technology, Rajamangala University of Technology Isan, Nakhon Ratchasima 30000, Thailand
[e] Sustainable Infrastructure Research and Development Center, Dept. of Civil Engineering, Faculty of Engineering, Khon Kaen University, Khon Kaen 40002, Thailand
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Project duration: 3 year, from 1/Nov/2021 to 31/Oct/2024

Current progress: 80 %

Abstract:
This work presents a feasibility study on the use of alkali-activated/cement powder (AACP) paste as a potential coating material for improving the durability of structures and protecting buildings exposed to marine environments. The AACP was synthesized by geopolymer powder (GP), Portland cement (PC), and silica fume (SF). The experimental tests consisted of the retained compressive strength and weight change after exposure to 5% sulfuric acid (H_2SO_4) solution and 5% magnesium sulfate ($MgSO_4$) solution, and chloride migration coefficient (RCM). The corrosion probability of concrete reinforcement with surface treatment of deformed bar using the half-cell potential (HCP) test was also evaluated. Test results showed that the AACP paste exhibited superior durability to PC paste, as evidenced by its relatively low strength loss. In addition, the chloride diffusion coefficient of AACP pastes was lower than that of PC paste. For the corrosion probability of concrete reinforcement, the average HCP values of the AACP paste-treated-deformed bar were lower than those of the no-treated or PC paste-treated-deformed bar.

Rationales/Problem statements:
The one of the major deterioration mechanisms of reinforced concrete structures is steel corrosion to when they are exposed to the environments containing chlorides and/or carbon dioxide. The corrosion of reinforcing steel results in a volume expansion while the solid iron transforms to liquid rust, which generates internal pressures and leads surrounding concrete cracking. The cracks in turn will accelerate the transport of chlorides, which will further speed up the corrosion process, and finally leads concrete delamination, and structural collapse. The coating technique is the most commonly used one owing to its cost-effectiveness and simplicity to be directly used on steel bars and/or on concrete surfaces. The coating materials with low cost, excellent durability, and equivalent mechanical properties to commercial coating materials should be developed.

Recently, the use of alkali-activated binder (AAB) as coatings in construction work has been developed because AAB is equivalent to commercial coating materials regarding setting time, strength, bond behavior, and durability properties.

Objectives:
Therefore, this research aims to study the durability properties of novel coating material made from the AACP. The knowledge gained would be beneficial for the future use of AACP as alternative coating materials.

Progress/Findings/Results:
The immersion of the AACP and PC pastes in tap water helped the formation of their reaction products within the matrix, therefore, results in growth of their strength for all mixtures. After 30 days of submersion in tap water, the AACP paste produced by the GP containing PC developed substantially greater strength than the AACP paste produced by the GP without PC. This is because the reaction of hydration products and major chemical compositions from precursors under the optimum humidity conditions that could accelerate the reaction degree within the matrix. However, there was a little improvement as the submerged duration increased.

The strength of the AACP paste synthesized by the GP without PC increased after exposure to 5% magnesium sulfate and 5% sulfuric acid solutions for 30 days; but decreased slightly as the duration of immersion increased. In contrast, the AACP paste produced by the GP with PC slightly decreased since the 30-day submerged duration, which is similar to the PC pastes. In addition, the reaction of 5% magnesium sulfate solution on paste is severe than that of 5% sulfuric acid solution.

The resistances of the AACP paste to 5% sulfuric acid and 5% magnesium sulfate solutions were greater than those of the PC pastes in terms of low strength loss and weight change. The gypsum and magnesium hydroxide were commonly products of the interaction

The chloride migration coefficient of the AACP pastes was lower than that of the PC pastes about 32.7 to 77.6 times for the 100PC paste and 3.0 to 7.1 times for the PC with FA+SF paste. The excellent chloride resistance of the AACP paste was confirmed by low chloride penetration after spraying the AgNO3 solution on the surface. This indicated that there will be less durability issues caused by the attack of chloride ions.

The average HCP readings for the DB coated with AACP paste produced by GP without PC had a corrosion level ranging from low to moderate at the time of measurement after the acceleration of steel corrosion for 3 hours, indicating that AACP coating can provide an excellent protection to the corrosion of reinforcing steel in concrete. However, the corrosion probability of the AACP paste prepared by the GP with PC exceeded 90% at the time of measurement, which is similar to the 100PC and PC with FA+SF pastes. Moreover, the effect of the NS-to-NH ratio and curing temperature had no significant impact on their corrosion levels.

Conclusion:
The AACP paste-coated DB is recommended as a technique of protecting buildings exposed to marine environments.

Current Output:

1) Chattarika Phiangphimai, Gonganok Joinok, Tanakorn Phoo-ngernkham, Sakonwan Hanjitsuwan, Nattapong Damrongwiriyanupap, Worathep Sae-Long, Piti Sukontasukkul, and Prinya Chindaprasirt (2023), "Shrinkage, compressive and bond strengths of alkali activated/cement powder for alternative coating applications". Construction and Building Materials, 400, 132631.

2) Chattarika Phiangphimai, Gonganok Joinok, Tanakorn Phoo-ngernkham, Nattapong Damrongwiriyanupap, Sakonwan Hanjitsuwan, Cherdsak Suksiripattanapong, Piti Sukontasukkul, and Prinya Chindaprasirt (2022), "Durability Properties of Novel Coating Material Produced by Alkali-Activated/Cement Powder". Construction and Building Materials, 363, 129837.

Challenges/Problems and Possible solutions:

-

Future plan:

A minimum of five international papers will be submitted to the expected journal as the outputs of this research. The journal with the highest impact factor in the field of construction materials is Construction Building and Materials/Case Studies in Construction Materials/Materials and Structures/Cement and Concrete Composites.

BRAINPOWER CONGRESS 2023
ร่วมกันสร้างและขับเคลื่อนงานวิจัยขั้นแนวหน้า
สู่อุตสาหกรรมแห่งอนาคต

ด้าน Global Partnerships (Chemistry, Biology, Environmental)

Monitoring and Optimization of Mangrove Restoration for Sustainable Management of Coastal Ecosystems in Southeast Asia

Acronym: Monitoring and REstoration for Sustainable Coastal Ecosystems (RESCuE-2)

Uday Pimple[a]*, Poonsri Wanthongchai[b], Kumron Leadprathom[c], Sukan Pungkul[d], Tamanai Pravinvongvuthi[b], Suchart Yamprasai[b], Dario Simonetti[e], Patiya Kemacheevakul[f], Valery Gond[g], Kim Soben[h], Behara Satyanarayana[i], Sara Fratini[j], Uta Berger[k*], Claude Garcia[l*], Farid Dahdouh-Guebas[m]*

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Project duration: 3 years, from 1 April 2023 to 31 March2026

Current progress: 15-20 %

Abstract: Mangroves are among the most carbon-rich forests serving as long-term carbon sinks for sequestration to mitigate climate change. Thus, mangrove loss and degradation cause extensive damage to human life, health, wellbeing, and the environment. Therefore, the United Nations Decade on Ecosystem Restoration (2021–2030) lists coastal ecosystems/ mangroves as a restoration priority, but the plethora of ongoing restoration efforts are behind its potential. The project Monitoring and REstoration for Sustainable Coastal Ecosystems (RESCuE-2) will contribute to developing such a framework connecting local activities with medium- and large-scale, spatio-temporal information required for effective restoration interventions and appropriate solutions. It builds on existing closed collaboration among scientists from Europe, SEA, Japan, national policy makers from government agencies and local communities. In Thailand, the main goal of the project is to develop and implement country-specific decision-support tools for mapping and monitoring the distribution, loss and change of species diversity.

Rationales/Problem statements: Gaps in our understanding of the relationship between environmental driving factors, mangrove diversity, and their sequestration potential severely limit our ability to assess the values of carbon sequestration and biodiversity for conservation. Based on the research outcomes of the former RESCuE-1 project (https://rescue-pro.net/), we identified the factors hindering adequate reporting and spatial-scale monitoring. In addition, we identified the factors interfering with field inventory, remote sensing-based monitoring, and modeling-based predictions and proposed the best practices to overcome these problems. As a contribution to the United Nations Decade for Ecosystem Restoration 2021-2030 with the aim of restoring mangrove biodiversity, halting the loss and degradation of mangroves, while increasing the long-term sustainability of current and future rehabilitation efforts on the mangrove ecosystem in Thailand and SEA. Based on remote sensing and modeling approaches, the potential and effectiveness of restoration measures will also be assessed by linking to the local community's wellbeing.

Objectives: The below scientific and / or technical work objectives were identified.

1. Develop and implement country-specific decision-support tools for mapping and monitoring distribution, loss and change of mangrove species diversity (Thailand)
2. Continue and maintain a network of environmental sensors in Trat province (Thailand)
3. Developing the modeling-based tool to enhance rehabilitation practices on a scientific basis (Germany)
4. An assessment of the status of ecosystem services at individual sites derived from natural and restored mangroves (Switzerland and Belgium)
5. Dissemination of knowledge on status. The impact of conservation measures will be communicated to local communities and national authorities.

Progress/Findings/Results: The contributions during the reporting period includes:

1. Project implementation meetings were carried out on May 31 with all consortium members, and June 08 and October 16, 2023
2. The cooperation agreement (the "Agreement") has been signed between Technische Universität Dresden, Germany, Université libre de Bruxelles, Belgium, Berner Fachhochschule, Switzerland and the King Mongkut University of Technology Thonburi, Thailand
3. The Memorandum of Understanding (MoU) has been signed with the Department of Marine and Coastal Resources, Thailand
4. The project website domain has been registered and full website is under development (https://rescue-pro.net/)
5. The project kick-off meeting took place between November 21 - December 01, 2023
6. The preliminary site assessment has been completed.

Conclusion: The close partnerships between key government policy makers and project scientists were established, this will substantially contribute to achieve the final project goals. The official project website domain was established (https://rescue-pro.net/), all project activities will be posted on this website. The website will be a binding element between networking activities, joint research activities and serves as a complimentary part of project information dissemination and outreach strategy.

Current Output:

1. The cooperation agreement
2. The Memorandum of Understanding (MoU)
3. Project website: https://rescue-pro.net/
4. Kickoff meeting report is in progress.

Challenges/Problems and Possible solutions: Due to different project starting dates from individual funded countries, the kickoff meeting was delayed. However, project leaders have completed required paperwork in time and organised the kickoff meeting.

Future plan: The project will focus on the collection of systematic inventory data, which will be the starting point for a long-term database on mangrove species occurrence, species coexistence and corresponding habitat characteristics. Further, this data will be integrated to remote sensing, modeling-based framework and ecosystem services pursued by local communities.

Multi-scale Simulations and Design for CO_2 Recycling Related Processes

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Project duration: 3 years, from 1 April 2022 to 31 March 2025

Current progress: 30%

Abstract: This is a cooperative research project between Osaka University (Prof. Yoshitada Morikawa), Chulalongkorn University (Prof. Joongjai Panpranot), and Institute Technology Bandung, Indonesia. It aims to mitigate the global worming problem by designing materials for CO_2 recycling and related processes such as CO_2 capture and hydrogenation, direct methanol fuel cell electrocatalysts and next generation batteries by using multi-scale computer simulation methods with electronic structure theory and machine learning methods in collaboration with experimental study. In the first year, formation of nanocrystalline solid carbon including nano-graphene and single crystalline nanodiamond films under the room-temperature CO_2 electrochemical reduction system has been demonstrated. Based on the corroborative DFT findings, the formation of crystalline carbon films containing nanodiamond is proposed to occur through the electrochemical reduction of CO_2 to CO^* followed by CO disproportionation reaction (Boudouard reaction), which was facilitated by high localized electric field on small metal clusters with excess electrons.

Rationales/Problem statements: Climate change is one of the most significant challenges confronting the current generation. In order to mitigate the detrimental impacts of climate change on both environment and living organisms, the anthropogenic CO_2 emission has to be substantially reduced. Transforming gaseous CO_2 into valuable solid carbon products while achieving a negative CO_2 emission is an aspirational ideal to cope with climate change and mitigate its impact. Solid carbon products are easier to store and handle and can get rid of leakage problems and technology for utilizing carbonaceous materials is readily available. However, the bottom-up synthesis to turn CO_2 into solid carbon such as chemical vapor deposition (CVD), molten salt electrolysis, and thermochemical synthesis requires massive energy consumption. Conversion of CO_2 into carbon nanostructures at room temperature and under atmospheric pressure is challenging but it can provide significant impact on the development of many future advanced technologies.

Objectives: Study the formation of solid nanocrystalline carbon by room temperature CO_2 electrochemical reduction reaction: effects of metal electrocatalysts and electrolyte and their potential applications in batteries and sensors.

Progress/Findings/Results: The formation and growth characteristics of nanostructured carbon films on nascent Ag clusters during room-temperature electrochemical CO_2 reduction reactions are demonstrated. Under a ternary electrolyte system containing $[BMIm]^+[BF_4]^-$, propylene carbonate, and water, a mixture of sp^2/sp^3 carbon allotropes were grown on the facets of Ag nanocrystals as building blocks. The growth of nanostructured carbon can be divided into three stages: Stage 1: sp^3-rich carbon and diamond seed formation; stage 2: diamond growth and diamond–graphite transformation; and stage 3: amorphous carbon formation. The conversion of CO_2 and high selectivity for the solid carbon products (>95%) were maintained during the full CO_2RR reaction length of 390 min. The results enable further design of the room-temperature production of nanostructured carbon allotropes and/or the corresponding metal-composites by a viable negative CO_2 emission technology. The room-temperature synthesis of polycrystalline nanographene was also achieved by CO_2RR over the electrodeposited Bi on Sn substrate prepared with various bismuth concentrations (0.01 M, 0.05 M, and 0.1 M). The solid carbon products were solely produced on all the prepared electrodes at the applied potential −1.1 V vs. Ag/AgCl and were characterized as polycrystalline nanographene with an average domain size of ca. 3–4 nm. The optimized negative potential for the formation of nanographene products on the 0.05Bi/Sn was ca. −1.5 V vs. Ag/AgCl. Increasing the negative value of the applied potential accelerated the agglomeration of the highly reactive nascent Bi clusters *in situ* formed under the reaction conditions, which, as a consequence, resulted in a slight deviation of the product selectivity toward gaseous CO and H_2 evolution reaction. The Bi–graphene composites produced by this method show high potential as an additive for working electrode modification in electrochemical sensor-related applications.

Conclusion: We present a breakthrough advancement in the growth of nanostructured carbon allotropes from CO_2 by the viable negative CO_2 emission approach. The nanocrystalline carbon was grown on the negatively charged metal nanoclusters (Ag, Bi, Ni, Co, and Zn) *in situ* formed by reduction and nanoclustering of the natural ultrathin oxide layers of the electrocatalyst during CO_2RR.

Current Output:

1) R. Nganglumpoon et al. “Growing 3D-nanostructured carbon allotropes from CO_2 at room temperature under the dynamic CO_2 electrochemical reduction environment”, *Carbon* 187, 241-255 (2002)
2) S. Watmanee et al. “Formation and growth characteristics of nanostructured carbon films on nascent Ag clusters during room-temperature electrochemical CO_2 reduction”, *Nanoscale Adv.* 4 2255-2267 (2002)
3) P. Pinthong et al. “Room Temperature Nanographene Production via CO_2 Electrochemical Reduction on the Electrodeposited Bi on Sn Substrate”, *Nanomaterials* 12 (9), 3389 (2022).
4) N. Hongrutai et al. “Electrochemical reduction of carbon dioxide on the oxide-containing electrocatalysts”, *J. CO_2 Utilization*, 64, 102194 (2022)
Patents: PCT/IB2022/061915
A PROCESS FOR PRODUCING A NANOCRYSTALLINE CARBON WITH 1D, 2D, OR 3D STRUCTURE AND/OR A NANOCRYSTALLINE DIAMOND AND/OR AN AMORPHOUS CARBON AND/OR A METAL-CARBON NANOMATERIAL COMPOSITE AND/OR A MIXTURE THEREO
Filing Date: 08.12.2022 Status: Pending

Challenges/Problems and Possible solutions: -

Future plan: Study the utilization of captured CO_2 as the carbon source to produce nanocrystalline carbon products and optimize reaction conditions and reactor configuration for scaled-up CO_2RR to solid carbon system

Research Network Strengthen on Interaction of Plant - Beneficial Microbes for Crop Production

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Project duration: 3 years, from 1 November 2021 to 31 October 2024

Current progress: 60%

Abstract:

This project pays attentions on in-depth research of plant-beneficial microbes for crop production. The new theory, new mechanism, and new application of plant-microbe interactions in aspects of (i) nodulation mechanism; (ii) nitrogen fixation mechanism; (iii) plant health stimulation and plant disease control mechanism; and (iv) plant growth promoting mechanism of other economic crops, are focusing. The recent findings in these aspects are listed below.

Rationales/Problem statements:

Nowadays, the theories of plant-microbe interaction mechanism are dynamics due to the modern techniques in molecular biology and microscopy have improved, it was found that the interactions between plant and beneficial microbes are sophisticated. The network strengthening between research partners who are specialize in different techniques but sharing the common interest of these plant-microbe interactions, are very important to develop the research and skills of young scientists in this field. This strategy of research network would bring the new knowledge and later create new innovation for sustainable crop production in Thailand.

Objectives:

1. To strengthen the network with the foreign research partner institutes and later extend the new collaboration to others
2. To develop the research potential of Thai researchers through the exchange of in-depth knowledge and technology
3. To create the high quality and high impact research in this field

Progress/Findings/Results:

The recent research findings were listed as following.

1. *Bradyrhizobium* SUTN9-2 contains two copies of T4SS clusters belonging to the *tra/trb* operon on chromosomes with different gene arrangements. The phylogenetic tree and gene annotation analysis predict the evolution of the *tra/trb* operon of rhizobia and suggests that the gene encoding the T4SS gene among *Bradyrhizobium* and *Mesorhizobium* may have coevolution. In addition, *Bradyrhizobium* has a uniquely arranged *copG*, *traG*, and *virD2* gene cluster. The results of $T4SS_1$ gene deletion and complementation revealed its positive effect on nodulation. Therefore, T4SS seems to be another determinant for symbiosis. This is the first report on the role of T4SS in *Bradyrhizobium* symbiosis.
2. *Bradyrhizobium* DOA9 contains 2 *rpoN* genes, located in the chromosome (*rpoNc*) and mega-plasmid (*rpoNp*). Mutation of either *rpoNc* or *rpoNp* affected cell surface polysaccharide formation, nodulation, and nitrogen fixation. Analysis of polysaccharide

produced from DOA9WT (wild-type) and mutants by Synchrotron-FTIR showed the peaks include –OH, CH_2, and CH_3 (lipid), C=O, –C–O–C (carbohydrate), and –COOH (protein) significantly differ in the pattern ratio of biological molecules of wild-type and mutant strains. The composition of polysaccharide directly affected the nodulation efficiency. Fe K-edge X-ray absorption near-edge structure and extended X-ray absorption fine structure analyses revealed deficiencies in the nitrogenase enzyme and leghemoglobin in the nodules of *rpoNc* mutant which indicates the influence of RpoN on nodulation and nitrogen fixation.

3. The recombinant single-chain fragment variable (scFv) antibody for detection and monitoring of bradyrhizobia were developed. Antibodies were selected based on the specific binding of antibody and bacterial cell. This scFv antibody produced by protein expression in *E. coli* without using animal and could be applied with ELISA or FA techniques for detection or monitoring of rhizobial cell in each step of biofertilizer production. The incorporation of total plate count technique with FA could be used to determine the number of living cell and distinguish each bradyrhizobial strain in the mixed culture inoculant.

4. Tailored matching and engineering of cannabis endophytic bacterial microbiomes were developed for plant growth and metabolite promotions. Endophytic microbiomes of cannabis plant grew in soil and in the planting material were examined, while the culturable bacteria were also isolated and determined their PGP traits. After re-inoculation into cannabis, 8 from 18 isolates were found to localize inside the plant tissue and promoted plant growth and THC concentration. Therefore, this strategy can be used to engineer microbiome for other economic plant growth promotion.

5. *Bacillus velezensis* S141 could be used as mycorrhiza helper bacteria (MHB). The strain S141 when co-inoculated on *Lotus japonicus* with arbuscular mycorrhizal fungus (AMF) *Rhizophagus irregularis*, improved its plant root colonization and AMF spore production. The co-inoculation of S141 stimulated plant genes expression involving in AMF symbiosis, while stimulated AMF cell cycle-related genes but reduce the expression of genes involved in phosphorus and sugar transporter when compared with a single AMF inoculation.

Conclusion:

This work reports the role of T4SS and RpoN in *Bradyrhizobium* symbiosis, while some PGPR can act as MHB stimulate AMF colonization and spore production. This project also paves the way of using microbiome engineering to create high efficiency biofertilizer and the way of using scFv antibody for detection and monitoring.

Current Output:

For the whole project produced the publication in

Q1 = 4; Q2 = 3; manuscripts under review = 2; and manuscript in preparation = 1

Challenges/Problems and Possible solutions: None

Future plan:

Proceed in-dept research on *Bradyrhizobium*-legume nodulation and nitrogen fixation mechanism as well as the interactions and application of these beneficial microbes for crop production. Two workshops will be arranged to upskill Thai scientists and students. Moreover, the Asian-Pacific Conference on Plant-Microbe Symbiosis and Nitrogen fixation (6^{th} APMNF, Thailand 2024) will be held in Chiang Mai during 7-9 January, 2024 to extend the network in this field.

Greenhouse Gas Reduction in RICE: MICRO-biome Climate Smart Applications

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Project duration: 3 year, from 1 April 2023 to 31 March 2026

Current progress 13%

Greenhouse gases (GHGs) are the main causes of climate change. The primary greenhouse gases are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Modern agricultural practices largely rely on high inputs of mineral fertilizers to obtain high yields and in particular, rice agriculture, relies in flooding regimes. Next to the significant stress on water availability, flooding results in anoxic conditions that lead to the production of GHG. In anoxic paddies, CH_4 is produced by the methanogenic archaea and part of it is oxidized by the methanotrophic bacteria and/or archaea coupled to denitrification or metal reduction. Significant progress has been done in the characterization of GHG emissions in Asian rice agricultural systems and fertilization and water management strategies (i.e., AWD (Alternating Wetting and Drying)) to mitigate GHG emissions. However, microbial GHG mitigation has not been fully researched as a suitable biotechnological application. In this project, we investigate ways to enhance the native beneficial microbiology of the rice paddies where methane oxidation is enhanced and N_2O.

The anoxic conditions prevailing in submerged rice paddy fields create an environment favor the anaerobic metabolisms of methanogenic archaea, leading to the emission of methane, a potent greenhouse gas.

Understanding the factors influencing methanogenic activity such as substrate availability in rice soils is crucial for developing effective mitigation strategies to reduce methane emissions and their impact on climate change.

In recent years, methanotrophic research studies are becoming more frequent than in the past to find out the methanotrophic communities and methane oxidation rates under different soil conditions and types, and even with different parameters. Even though there are a lot of research, it is still far away from complete understanding of the behavior methanotrophic activity. Lacking accurate data about the methane oxidation is also one of the issues for estimating accurate GHGs emissions. Especially in Southeast Asia countries where the development and research studies are still lacking compared to the Western countries.

That is why this study will focus on the rice paddy soil from one of Thailand's regions and learn about the methane oxidation towards the development of a microbial biotech application that enhances methane oxidation and enables climate-sustainable rice agriculture.

Specific objectives:

(1) Isolate and characterize a collection of microorganisms from two different geographical locations to create the proposed SynCom.

(2) Identify common methanotrophic and nitrous oxide reducing microorganisms in European and Thai rice soils combined with nitrogen fixation capabilities.

(3) Conduct mesocosm studies under controlled conditions to assess the effect of the SynCom on CH4 & N2O mitigation and plant growth yield.

(4) Translate the mesocosm studies into field experiments in real rice cultivation conditions (in Thailand) to determine the feasibility and proof-of-concept of the novel strategy of

microbial inoculations to manage soil GHG emissions while promoting rice growth and yield.

Progress/Findings/Results:

So far, I have been successful in achieving results in the preparatory activities:

1. Sampling site selection and sampling: securing samples in the pre-planting stages of soil core layers. And bulk soil from the post tillage and soil preparation for our mesocosm experiments (WP2).
2. Initial analysis of the soils: this is crucial to determine the soil quality and carbon to nitrogen ratio to design the experiments for the mesocosm experiments under different fertilization regimes.
3. DNA extraction for 16S microbial diversity analysis: which is the foundation for the microbial community characterization in the system over depths to identify hotspots for GHG activity.

These DNA samples were sent for outsourcing in the month of October, the results will be analyzed and we will know the microbial composition of the soils per slice in order to start the best enrichments for the construction of the synthetic microbial community.

4. This project is also a catalyst for global networking by deriving further project ideas for more funding oriented to exchange and capacity building: this has been achieved.

New consortium MIcroSOS: Microorganisms helping plants for resilient agriculture I proposed that this project could help me grow my network through a derived project idea. I initiated and with support from EU partners we secured a grant for exchange that will benefit our project greatly. Successfully acquired 257000 euros for a side project on capacity building which will benefit primarily the MicroGRICE employees and staff.

Conclusion: MicroGRICE is a successful international consortium, that has achieved to expand into 8 partners in 5 additional EU countries where the staff from this project can benefit by acquiring advanced knowledge into biotech possibilities for Thai agriculture.

Current Output: Acquisition of additional consortium with 8 EU partners, where MicroGRICE will benefit with additional international expertise. In addition, this brings more collaborations with Thai researchers to enhance the impact of the advancements in rice agriculture.

Challenges/Problems and Possible solutions: Funding was delayed by 2 months, which has resulted that for the first 6 months of the project we only could be active in 4 resulting in a delay in more results. Solution: to rely in the expanded network for output and collaboration to do research lines that compliment MicroGRICE.

Future plan: finalize the characterization of microbial community in soil depths, and document the methane fluxes over full planting season.

Nanotechnology Routes for the Design of High-performance CO_2 Methanation Catalysts

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Project duration: 3 year, from 1 October 2021 to 31 September 2024
Current progress: 75%

Abstract:

Ru supported on Ti-modified SiO_2 catalysts had been prepared by using one-step flame spray pyrolysis. The obtained catalysts were tested in CO_2 methanation reaction and characterized by using multi techniques such as N_2 physisorption, X-ray diffraction, CO-chemisorption, XPS and in-situ IR Drift spectroscopy. Addition of Ti in flame reactor resulted in the formation of anatase and rutile TiO_2 phase, which improved the catalytic activity of Ru/SiO_2 catalysts. In order to compare the activity of flame-made catalysts, conventional impregnation of Ru on FSP-made Ti modified SiO_2 had been used. The reaction results revealed that the catalytic activity of impregnation-made catalysts was much higher than FSP-made one. In-situ IR Drift spectroscopy results showed the different CH_4 formation mechanisms of both catalysts. the formation of CH_4 on FSP-made catalysts occurred through the CO route, while, the impregnation-made catalysts might proceed via both dissociative adsorption of CO_2 and the formation of surface formates.

Rationales/Problem statements:

Carbon dioxide is known as the main pollutant that can lead to global warming and climate shift. Thus, it is very necessary to control the CO_2 emission into the air by converting the carbon dioxide in to value-added compound. Methanation reaction is the reaction that can converts carbon dioxide and hydrogen, and is a popular method of hydrogen retention which can reduced the carbon dioxide content.

Although, there are many several benefit of the CO_2 hydrogenation to methane due to its simple reaction and can be operated under atmospheric pressure, however, the conversion was still quite low and catalyst activity is needed improvement. Among all catalysts Ru–based catalysts having high catalytic activity and stability over a wide range of operating conditions had more potential.

In this work, Ru supported on Ti modified SiO_2 catalysts were prepared by various techniques. The physiochemical properties of the catalysts were characterized and tested in CO_2 methanation reaction.

Objectives:

Combine the strength of three research groups from Belgium, Switzerland and Thailand to build up promising catalytic nanomaterials for the CO_2 methanation process and make such a process feasible for the use in industrial-scale processes

Progress/Findings/Results:

In this work, $Ru/Ti\text{-}SiO_2$ catalysts had been synthesized by using one-step flame spray pyrolysis. From XRD pattern, $F\text{-}Ru\text{-}SiO_2$ catalyst exhibited the major broad XRD band structure of amorphous phase of SiO_2 with addition peaks of RuO_2 phase. Addition of Ti resulted in the formation of anatase and rutile TiO_2 phase. The peak intensity and the crystallite size of TiO_2 phase increased with increasing of Ti contents. BET surface area and total pore volume also increased from as the Ti loading content increased. Increasing of BET

surface area and total pore volume was probably due to the insertion of Ti molecule in SiO_2 matrix, which retard the crystal growth of SiO_2 particles. The amounts of Ru metal active sites and %metal dispersion of all FSP-made catalysts are measured by using H_2 chemisorption after reduction at 400 °C. Increased of Ti content from 0 to 12wt% resulted in the increase of amounts of H_2 chemisorption from 0.91 to 1.4 micromole/g-cat corresponding to the increase of percent dispersion from 1.8 to 2.7%.

The catalytic activity was carried out in CO_2 methanation reaction between 200 to 400°C. In all tests, there was no trace of CO formation in all catalysts. Among all catalysts, F-Ru-SiO_2 exhibited the lowest catalytic performance. Addition of Ti in resulted in the improvement of catalytic performance and F-Ru-12Ti-SiO_2 exhibited the highest CO_2 conversion.

To compare the catalytic performance, the Ru/Ti-SiO_2 catalysts have been synthesized by using conventional impregnation method. It clearly seen that the catalyst prepared by impregnation method exhibited much higher catalytic activities compare with flame-made one. Increasing of Ti doping in SiO_2 support also improved the catalytic activity of Ru catalysts and Ru/F-12Ti-SiO_2 exhibited highest CO_2 conversion of 53% at 400°C.

To understand the higher catalytic activity of impregnation-made catalyst, various characterization methods were applied. The XRD of pure support exhibited the broad band structure of amorphous silica with small peaks corresponding to anatase and rutile TiO_2 phases. After impregnate with Ru, the small peaks of RuO_2 were also observed. The crystal phases of fresh impregnation catalyst were quite similar to FSP-made one. However, after the reaction test, RuO_2 peaks in fresh catalysts sample were completely absence and the addition peak of Ru metal were clearly presented. This suggested that the RuO_2 on the impregnation-made catalyst was completely transformed to Ru metallic phase after the reaction. This phenomenon is quite different from the FSP-made catalysts, which only presented the partial reduction of RuO_2 phase after reaction and might be one of the reasons of higher catalytic performance of impregnation-made catalysts.

The CO_2 methanation mechanism and intermediate products of both Ru supported catalysts are also studied by using the operando in-situ DRIFTS methods**.** From the obtained results, it is clearly seen that addition of Ti promote the catalytic activity of Ru supported SiO_2 catalysts and impregnation-made catalysts exhibits higher catalytic activity than FSP-made one. In the case of FSP-made catalysts, the formation of CH_4 would occur through the CO route, while, the impregnation-made catalysts might proceed via dissociative adsorption of CO_2 and the formation of surface formats. Different in catalytic routes might use to explain the different in catalytic activity of both catalysts.

Conclusion:

Ru/Ti-SiO_2 catalysts have successfully been prepared in one-step flame spray pyrolysis. Addition of Ti resulted in formation of anatase and rutile TiO_2 mixed in the catalyst particles. Increasing of Ti loading improved the catalytic activity in CO_2 methanation. Presence of TiO_2 phase promote the catalytic activity by increasing of Ru dispersion and retard the RuO_2 sintering during the high temperature process. However, the catalytic activity of FSP-made catalysts is much lower than the impregnation-made one. From in-situ IR Drift spectra results, the formation of CH_4 of FSP-made catalysts might probably occurred through the CO route, while, the impregnation-made catalysts might proceed via dissociative adsorption of CO_2 and the formation of surface formates. The different in CH_4 methanation mechanism might probably due to the different stage of Ru species in the reaction process.

Current Output:

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Challenges/Problems and Possible solutions:

In the first year, every research group focus on the study of Ru/SiO_2 catalyst by various methods to use as the model to study the CO_2 methanation reaction mechanism. All results revealed that the catalytic activity of all Ru/SiO_2 catalysts are much lower than reference Ru/TiO_2 catalysts, which made it hard to publish. Therefore, every research groups try to improve the results by various means. Belgium group try to modify the catalytic activity by doping various metals on SiO_2 support. Swiss group will focus on preparation and testing of Ru catalyst with different Ti-O-Ru bonds. Thailand group found that the catalytic activity of impregnation-made catalyst is much higher than FSP-made one. Moreover, we have sent some sample to characterize in Belgium and Switzerland and we have done the molecular simulation to support all experiment results. In September, our research groups went to visit with Prof. Debecker groups at Belgium and plan to publish 2 papers.

Future plan:

The next step of this project is focus on the molecular simulation in CO_2 methanation on various catalysts in order to fully understand the reaction mechanism and deactivation process. The obtained result will compare with lab data. Then, the selected catalyst with the most activity and selectivity reaction will be tested in pilot-scale reactor.

Methanol Synthesis via CO_2 Hydrogenation using a Tailor-made Catalytic Membrane Reactor

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Project duration: 3 year, from 21 April 2023 to 20 April 2026
Current progress: 30%

Abstract:
This project proposes a method for CO_2 utilization by converting it into methanol using a custom-made membrane reactor. The objective is to establish a crucial element for economically viable direct CO_2 conversion, thereby reducing emissions and utilizing methanol as a storage medium for green hydrogen. The development includes a three-layer catalytic membrane: (1) Tailor-Made catalyst for methanol synthesis, based on Cu-Zn catalytic system nanoparticles, with investigations into the impact of Zr dopants and Al_2O_3 supports on catalytic performance. (2) Hydrophilic microporous zeolites, synthesized as zeolites NaA using a two-step hydrothermal and template-free process to minimize defects and optimize water separation properties. (3) α-Al_2O_3 tubes as membrane support, utilizing α-Al_2O_3 tubes as a robust membrane support for zeolite growth. This integrated approach aims to create an efficient and stable catalytic membrane reactor for the selective conversion of CO_2 to methanol.

Rationales/Problem statements:

1. To separate water from the formed methanol during the reaction, potentially avoiding the cost-intensive downstream rectification.
2. To acquire in-depth knowledge and expertise in conducting CO_2 hydrogenation to methanol using a lab-scale membrane reactor process.
3. To facilitate the transfer of knowledge and resources and share outcomes among all research parties.
4. To explore alternative ideas for mitigating CO_2 and other greenhouse gases.

Objectives:

1. Develop a three-layered catalytic membrane.
2. Characterize the membrane using various analyses, including BET, XRF, XRD, XPS, SEM, TGA, permporometry, and TPR/TPO/TPD/TPRx.
3. Optimize operating conditions, focusing on temperature, pressure, CO_2 conversion rate, and water permeation rate to prevent zeolite deactivation.
4. Test the lab-prepared membrane system for CO_2 hydrogenation, measuring CO_2 conversion, methanol selectivity, water permeation rate, separation factor, and stability via time on stream experiments.

Progress/Findings/Results:
The study investigated the CuO-ZnO-ZrO_2-Al2O_3 catalyst, synthesized through the precipitation method, and zeolite NaA nanoparticles, produced via the hydrothermal method. The nanomaterial had a composition of 1.8Al_2O_3:11.23SiO_2:0.6Na_2O:13.4(TMA)2O:700H_2O. Subsequently, membrane zeolite NaA was grown on an aluminum tube with a molar ratio of 1Al_2O_3:5SiO_2:50Na_2O:1000H_2O. In the XRD analysis, the catalyst exhibited distinctive spectral patterns. Notably, discernible peaks for CuO, ZnO, and ZrO_2 were absent, while distinct peaks for Al_2O_3 indicated its envelopment in an amorphous or nanocrystalline phase. The diffraction peaks aligned with characteristic crystallographic planes (3 1 1), (4 0 0), (5 1 1), and (4 4 0), confirming the

presence of Al_2O_3 (card no. 01-080-0955). Additionally, the X-ray diffraction spectrum of zeolite NaA showed distinct peaks corresponding to crystallographic planes (2 0 0), (2 2 0), (2 2 2), (4 2 0), (6 0 0), (6 2 2), (6 4 2), (8 2 0), and (6 6 4), consistent with prior research and confirming its structural integrity.

Conclusion:

In summary, this project innovatively converts CO_2 into methanol using a carefully designed membrane reactor. The main goal is to establish a key component for economically viable direct CO_2 conversion, reducing emissions, and utilizing methanol for green hydrogen storage. The project involves developing a three-layer catalytic membrane, including a Tailor-Made catalyst, hydrophilic zeolites (like NaA), and robust α-Al_2O_3 tubes as a membrane support. Key to success is synthesizing the catalyst, exploring Cu-Zn nanoparticles with Zr dopants and Al_2O_3 supports. Meticulous zeolite synthesis minimizes defects, and characterizing the catalyst on the zeolitic membrane is crucial for an efficient and stable reactor. Achieving these milestones can significantly advance CO_2 conversion, contributing to a more sustainable future.

Current Output:

1. A novel catalyst system.
2. Tailor-made zeolite.
3. Characteristics of the catalyst and zeolite.

Challenges/Problems and Possible solutions:

Future plan:

1. Preparation of the zeolitic membrane.
2. Dip-coating the catalyst onto the zeolitic membrane.
3. Characterization of the catalyst on the zeolitic membrane, including BET, XRD, SEM, etc.
4. Hydrogenation of CO2 to methanol is conducted in the reactor, varying the operational parameters.

Potential Evaluation of Urban Bioretention Design

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 71%

Abstract:
This research combines the development concept to reduce environmental impact called Water Sensitive Urban Design (WSUD) to be tested in Thailand. Its purpose is to reduce the impact of urban growth, causing problems with water flowing and flooding, in which infrastructures and buildings replace the natural landscape. This research has a total period of 3 years. It is divided into three parts: 1) review the design patterns and evaluate the potential for reducing stormwater runoff and filtration efficiency with computer models, 2) conduct the site experiment with local substances and analyze the costs and benefits, and 3) compare the results and presents the guidelines. The results show the runoff reduction of the six mesocosms is 100% from 8%, and the filtration efficiency increase of TSS is 7%, TN 13%, and TP 0%. The upcoming activities are conducting the training workshops and publishing the WSUD design guideline for Thailand's contexts.

Rationales/Problem statements:
The occurrence of stormwater runoff has a direct impact on living in urban areas. Due to the density of living and the intensity of land use, it contrasts with having water catchment areas or natural water porous areas. There are also efforts to encourage the use of alternative designs that focus on increasing the capacity of areas to receive water in urban areas (water-sensitive urban design -WSUD). (Sani Limthongsakul, 2011) There is an incentive for real estate developers in Bangkok called increasing the building area to land area ratio (FAR bonus). There will be a FAR bonus if water can be stored from 1 cubic meter to 4 cu.m. per 50 sq.m. of land area. (Ministry of Interior, 2013). WSUD is accepted that it can significantly reduce stormwater runoff in urban areas both in Thailand and abroad. (Choruengwiwat et al., 2019)

Objectives:
1. Study the patterns of water-sensitive urban design -WSUD to reduce stormwater runoff
2. Evaluate the potential for reducing stormwater runoff and filtration efficiency of water-sensitive urban design -WSUD with computer models
3. Conduct the site experiment to determine the efficiency in reducing stormwater runoff and filtration efficiency of water-sensitive urban design -WSUD.
4. Analyze the cost-benefit of water-sensitive urban design -WSUD.
5. Compare and present the water-sensitive urban design -WSUD guidelines

Progress/Findings/Results:
1. Study the patterns of WSUD to reduce stormwater runoff.

In studying the pattern of the WSUD from various design standards from abroad and literature review data can be defined for import into the EPA SWMM program with data that meets the following criteria required for calculations:

1) Information defining the base area in the model – Faculty of Engineering, CMU. The area is approximately 103 rai as the base case.

2) Rainfall information

As for rainfall, the rainfall values of the Mueang District, Chiang Mai Province, were selected using data from the relationship between IDF-curve. The 3-month ARI rainfall values are facilitated on field study; only the rainfall values from the 4 hours with the highest rainfall values were selected. The resulting rainfall value is 202 liters.

3) The urban water quality: Chiang Mai's area is within a 5 km—radius of the center. A Mae Kha Canal separates the two, and the direction is in the middle of the city. The water quality in the source water is at the Category 5 level. The water quality was selected TSS, TN, and TP

4) Prototype of WSUD-Bioretention and the water quality by specifying six alternative models by determining the base area. Therefore, there are seven types of situations: 3 types of not planting plants, three types of planting plants, and 1 type of natural original soil.

2. Computerized potential assessment process

The process for assessing the potential by computer of biological catchment areas (Bioretention) is the calculation of data on the EPA SWMM program, divided into three main parts: 1) Data modeling using the EPA SWMM program and calculating the potential of WSUD, 2) Verification of computer simulation results with virtual physical conditions. Moreover, 3) Present the results and evaluation.

3. Selecting a WSUD mesocosm experiment.

WSUD mesocosm for outdoor experiments as mesocosm. The design was concluded to consist of 4 layers: 1) the water receiving pond (Ponding), 2) the water filtering layer (Filter media), and 3) the transmission layer (Transition). 4) Storage layer. The size of the water receiving area in this study required a cross-sectional size of 0.6 meters in width and 1.8 meters in length to obtain an area of 1.08 sq.m. close to a unit area of 1 sq.m, and a water-bearing layer 1.1 high. m,

4. Testing to determine the efficiency of reducing stormwater runoff and filtering efficiency of WSUD: contain with 1) Testing the properties of WSUD composite substance: particle size, density (g/cm^3), porosity, volume fraction, Hydraulic Conductivity (mm/hr), TN and TP (%) and 2) Efficiency of WSUD removal of pollutants: the results have shown that WSUD determined the efficiency of reducing the amount of pollutants in the water, it was found that planting crops increased the efficiency of total nitrogen removal. However, WSUD did not significantly affect the efficiency of removing TSS and TN at 24 hours and 72 hours.

5. Cost Benefit Analysis of WSUD as EIRR -60 to -69%, and B/C Ration is -8 to -14%

Conclusion:

The research proceeded according to the activities in parts 1) and 2) and was completed according to the plan. The mesocosm is conducted with the pattern and local substances. The EPA-SWMM evaluates the results. The research carries out activities in part3). The four articles have been published in academic journals such as Scopus Q1. Another article is under the acceptance consideration. In terms of global partnerships, the researcher has developed the knowledge and abilities of the research team through study visits both domestically and abroad, from the researcher of Deakin University, Australia, and the National Taiwan University, Taiwan.

Current Output:

Publication of international academic articles in the ISI or Scopus Q1 databases.

1. Article: Eco-efficiency of green infrastructure on thermal comfort of outdoor spaces design. MDPI journals – Published https://www.mdpi.com/2071-1050/15/3/2566
2. Article: The Potential of a Tree to Increase Comfort Hours in Campus Public Space Design. Energy Reports -- (Published https://doi.org/10.1016/j.egyr.2023.05.258)

3. Article: The influence of bioretention assets on the outdoor thermal comfort in urban area. Energy Reports, (Published https://doi.org/10.1016/j.egyr.2023.05.257)
4. Article: Economics and cost-effectiveness of rain garden for flood-resistant urban design. Global Journal of Environmental Science and Management, 9(4) (Published https://www.gjesm.net/article_704363.html)
5. Article: Who benefits from nature? Bioretention landscapes and perceived safety: age, gender, and country. Cities, A, B. (Submitted status).

Challenges/Problems and Possible solutions:

1. Problem: The index values for the Scopus Q1 academic journal quality analysis changed during the article review stage.
   Solved: We are looking for alternative journals to submit the articles and inform the funding.
2. Problem: The allocation of the period of research exchange time is still being determined and delayed between Thai and foreign researchers. It is caused by the working and traveling periods and the budgets.
   Solved: We divided the trip into short periods for each available group and requested an advance payment from the faculty to reserve expenses.

Future plan:

January: We will welcome the research team from National Taiwan University and hold a symposium to exchange and collaborate on research.
February-April: writing the WSUD guidelines and filming WSUD CMU MOOC clips.
March: 1) organize WSUD Training Workshop and summarize the workshop results, and 2) revise WSUD guidelines and edit WSUD CMU MOOC clips.
June: prepare and summarize research project results and travel to meet with foreign researchers / make corrections according to meetings.
September: summarize the research results and outputs and publish WSUD guidelines.

Developing a Dynamic Digital Twin for Sustainable Smart Campus Management

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Project duration: 3 years, from 1 November 2021 to 31 October 2024
Current progress: 67%

Abstract:
Chiang Mai University has set a policy to transform its campuses into sustainable smart campuses. This vision materializes through the Dynamic Digital Twin for Sustainable Smart Campus Management project, a research and development initiative focused on the university's main campus. It installs sensors and surveys data from various agencies that have been measured and stored. They are designing a dashboard to visualize the data and creating a process for data connection by integrating physical data and various compiled information into a three-dimensional information platform, which will transmit the data to the dashboard through various data transmission algorithms. It was discovered that the initially used model could not be displayed separately as planned. Subsequently, the 3D model had to be divided into these four parts. With the creation of an algorithm to connect the data, the segmented model and grouping process were efficiently displayed on the initial website.

Rationales/Problem statements:
The Ministry of Digital Economy and Society (MDES) in Thailand has designated the Digital Economy Promotion Agency (DEPA) to spearhead the development of smart cities, with Chiang Mai leading the way as the first province in this initiative. Collaborating with Chiang Mai University, the province is poised to embrace the digital era, supporting sustainable solutions for its aging population. Aligned with its commitment to Sustainable Development Goals (SDGs), Chiang Mai University has set a policy to transform its campuses into sustainable smart campuses. This vision materializes through the Dynamic Digital Twin for Sustainable Smart Campus Management project, a research and development initiative focused on the university's main campus, covering approximately **2.9** square kilometers.

Objectives:
Studying user requirements from individuals working in physical building management to contribute to the development of a suitable physical-digital model. Contributing a suitable physical-digital model that aligns with user requirements and is a prototype for future development. Establishing a connection between the physical and digital model and the area for effective resource management. Promoting an efficient and user-friendly resource management system through a Web Portal or Dashboard.

Progress/Findings/Results:
It executes the installation of planned sensor equipment and surveys data from various agencies that have been measured and stored. It assesses the availability of data on small dust particles, temperature, humidity, and electrical energy to determine relevance. If the required information has already been collected, coordinate to request permission for its use. Design and plan the development of a dashboard to visualize the data. The dashboard will

be structured into four sections corresponding to different physical data levels: faculty level, building level, floor level, and room level. It creates a process for data connection by integrating physical data and various compiled information into a three-dimensional information platform, which will transmit the data to the dashboard through various data transmission algorithms.

The information collected from the sensor device can be categorized into new data collection groups: Information received from sensor devices and information obtained from agencies. The data sharing scope from sensor devices is further classified into Outdoor sensor data, which will gather information on PM2.5, temperature, and relative humidity. This set of data is identified as environmental data. Another subset is the sensor data inside the building, encompassing environmental data, building energy usage, and room occupancy. The building energy usage is further categorized into the electrical lighting system, electrical power system, and air conditioning electrical systems. The last category involves information received from the agency, where the research project acquires building energy data from the ERDI agency and environmental data from the Dustboy project. From the website design and dashboard for displaying information, it is evident that the display is segmented into four parts: faculty-level information, building-level information, class-level information, and room-level information. The models separated in Step 2 will be utilized to reassemble the models, ensuring their suitability for displaying all four parts. Before grouping the data, the room model data needs to be prepared for grouping. Due to the nature of the model being imported into SuperMap iDesktop, data pieces such as walls, doors, and windows that do not meet the requirements will be selected.

Consequently, even if the model is segmented at the room level in Revit, upon importing it into the SuperMap platform, the model pieces must be merged again through the merging process. It allows the model to be selected for each room as needed. During the merging process, it is crucial to specify the ID of the room to use as a database for display.

Developing a suitable algorithm for presenting 3D model data facilitates the efficient display of models on websites or dashboards. This process stems from planning the dashboard to showcase data at various model levels. It is imperative to consider the segmented nature of the model and accurately identify different characteristics to ensure a comprehensive and accurate representation in the display.

Conclusion:

The renderings were regrouped explicitly for the 3D model of the building created from the modeling process. It was discovered that the initially used model could not be displayed separately as planned. Consequently, an algorithm was developed to link 3D models appropriately for website display. The findings indicated that to showcase the 3D model on the website; it was necessary to present a designed model in four parts. Subsequently, the 3D model had to be divided into these four parts. With the creation of an algorithm to connect the data, the segmented model and grouping process were efficiently displayed on the initial website.

Current Output:

Publication

- Chanpichaigosol N, Chaichana C, Buachart C, Tochaiwat K, Rinchumphu D. Analytical process of the energy efficiency in building improvement alternatives. Energy Reports. 2022; 8(15):31-37. [https://doi.org/10.1016/j.egyr.2022.10.110]
- Lakhan A, Sodhro AH, Majumdar A, Khuwuthyakorn P, Thinnukool O. A Lightweight Secure Adaptive Approach for Internet-of-Medical-Things Healthcare Applications in Edge-Cloud-Based Networks. Sensors. 2022; 22(6):2379. [https://doi.org/10.3390/s22062379]

- Lakhan A, Morten Groenli T, Majumdar A, Khuwuthyakorn P, Hussain Khoso F, Thinnukool O. Potent Blockchain-Enabled Socket RPC Internet of Healthcare Things (IoHT) Framework for Medical Enterprises. Sensors. 2022; 22(12):4346. [https://doi.org/10.3390/s22124346]
- Mastoi Q-u-a, Wah TY, Mohammed MA, Iqbal U, Kadry S, Majumdar A, Thinnukool O. Novel DERMA Fusion Technique for ECG Heartbeat Classification. Life. 2022; 12(6):842. [https://doi.org/10.3390/life12060842]
- Ahmed S, Lakhan A, Thinnukool O, Khuwuthyakorn P. Blockchain Socket Factories with RMI-Enabled Framework for Fine-Grained Healthcare Applications. Sensors. 2022; 22(15):5833. [https://doi.org/10.3390/s22155833]
- Tochaiwat K, Rinchumphu D, Dendoung T, Khumpaisal S. Applying Linear Hedonic Price Model to Measure the Impact of Responsible Property Investment Factors on Thailand Condominium Projects. Engineered Science. 2023; 24. [https://doi.org/10.30919/es924]

Challenges/Problems and Possible solutions:

Due to the COVID-**19** pandemic, the Thai researchers and Taiwanese researchers could not observe activities, so the timetable was changed to February and September **2023**, respectively. In addition, a researcher was supported to study for a Ph.D. at NTU. In addition, a professor from The University of Tokyo was invited to observe activities. Subsequently, sensors were damaged by the storm. Therefore, sensors were repaired and upgraded to prevent the weather conditions. Unfortunately, there were changes in the team of researchers due to some members being unavailable, leading to the introduction of new team members.

Future plan:

The research works in Phase 3 primarily focused on developing a Dashboard for data management. In the current year, the research team has successfully designed the dashboard and implemented the connecting algorithm using real data. Initial displays were established at the faculty and building levels, demonstrating that the 3D model data could be showcased as intended. Consequently, the research team plans to move forward with creating the remaining sections of the dashboard, specifically the floor and room-level displays. This isuue will enable the completion of the connection between model data and information, ensuring efficient data display in the future.

Enabling Waste Management Scheme in Response to Disaster and Climate Change

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Project duration: 3 year, from 31 October 2021 to 30 October 2024

Current progress: 71%

Abstract:

Two handbooks of disaster waste management (DWM) and plastic waste management (PWM) are developed by Collaborative Research Laboratory (CRL) to facilitate community and municipality to cope with the situation before, during and after disaster occur. The handbooks are ready to demonstrate in selected municipalities next year to ensure their useability. The preparation of DWM handbook will be disseminated in the Asia conference under the special session of Main Stream Disaster Waste in Asia. The project activities include the coverage of researcher exchange scheme, conducting of webinars and international conference in order to use institutional connection and expert experience in enhancing readiness and capacity of community and municipality to handle the situation of DW and PW in the future.

Rationales/Problem statements:

It is well aware the rapid change of global activities recently introduced the new normal of waste separation and composition. The need of adaptation to future waste management such as disaster and climate change waste are challenge due to lack of capacity and readiness in response to these issues. Although Thailand is not the country that often face disasters but the experiences from the Thai great flood in 2011and the increasing frequency of earthquake recently reflected the low capacity of the country readiness to encounter the immediate situation of disaster and hence caused a vast impact of loss and damage. Therefore, the Collaborative Research Laboratory (CRL) which comprise of NIES from Japan and KMUTT, KU form Thailand, is proposing research work, through its strengthening network, to enable the readiness of community and municipality in order to plan and prepare necessary steps of action in response to these future wastes.

Objectives:

1. To enable waste management scheme in Asia in response to disaster and climate change, by focusing on 3 topics: (1) waste management plan, (2) human resources and capacity building, and (3) technologies for implementing the waste management plan
2. To use the knowledge exchange mechanisms of the existing network, the Collaborative Research Laboratory (CRL), as a prototype model in expanding and strengthening our collaborations to other partners in Thailand and other Asian countries.

Progress/Findings/Results:

The research team visited municipalities and communities at Burirum and Nonthaburi province to extend disaster waste (DW) and plastic waste (PW) management knowledge to them as well as search and evaluate their readiness to cope with the situation of disaster and energy crisis. Currently the handbooks of DW management and PW management, as the result from visit and discussion, are mostly complete.

The DWM handbook aims to facilitate preparation of disaster waste management at local level on the basis of communication with communities and municipality and develop the collaborative step of actions between these two parties enabling the situation to handle disaster waste. The handbook comprises of three chapters: general knowledge, steps of action for communities and steps of actions for municipality with the coverage of different periods: before, during and after disaster occurred. The handbook is presented in the form of easy understanding and user friendly where users can follow decision trees for planning before disaster period and for implementing during and after disaster period. The section for communities focuses how to deal with disaster waste when it happened. The municipality section plays the key role in immediate actions of collection and storage during disaster and the re-habitation after disaster period. The weak point that we found is the preparation of temporary storage site (TSS) which is not of concern of municipality.

The structure of PWM handbook is similar to DWM handbook. In addition, we found that there is still an opportunity to increase percentage of at-source plastic utilization in community as they are well aware of the plastic waste separation. However, in term of plastic utilization to solid fuel such as refuse derived fuel (RDF), with the limited area in the community, they are not confident to this technology and are concerned on the correction and transportation as well as RDF end-used market in their area. In addition to this issue, municipality, with the view of private company turn-key, is expected to support transportation system as well as promote local market for RDF.

To close the gaps of some issues in the handbook including estimation of DW generation per household, three researchers were exchanged to NIES in Japan to learn the concept of estimation and its application in the case of Thailand. In term of joint activities between Thailand and Japan in order to strengthening network of DW and PW management, a series of webinar and two special sessions at two international conferences were conducted to follow up-to-date information and explore the idea of DW and PW management. We are struck in the of Q1 journal publication which are not accomplished within early time of project. So far, one has been accepted and two manuscripts are submitted. However, there are several attempts to submit our key result of research including technology development to meet the target in the coming year.

In term of network strengthening and result dissemination, our team is invited to present our handbook preparation in the session of Mainstream Disaster Waste in Asia as part of the international conference in March 2024 Mumbai India. We also hope, in this event, for the opportunity to formulate the network of disaster waste management in Asia and make further connection to other countries forming Hub of DWM in ASEAN as state in the proposal.

Conclusion:

The research activities went well as plan. DWM and PWM handbook under collaboration with NIES are almost ready to demonstrate in selected municipality next year. Our result of handbook preparation will be disclosed in the Asia conference of Disaster waste. It is expected that more manuscripts can be submitted to Q1 International journal in due time.

Current Output:

Prototype- The handbook of disaster waste management and plastic waste management are finish and will be implemented to the target municipality including Burirum, Nonthaburi, Chiangrai and Pitsanulok

Publication- 3 Q1 journal papers have been processed with one accepted and 2 submitted.
1 book chapter is under publishing and 2 manuscripts are submitted in international journal.
In addition, 6 conference papers are presented at international conference

Challenges/Problems and Possible solutions:

Project face challenges in term of publication due to nature of its content that belong to

management rather than technology. We have submitted some manuscripts to non Q1 journal, but with the coming condense scientific result, we expect to have at least 3 papers submitted in next progress. The initiate of joint project is underway which may need time to crystalized in order to meet the objective of each party.

Future plan:

In order to prove usability of the two handbooks, we plan to demonstrate the use of these handbook particularly the set up of temporary storage site (TSS) in our studied provinces (Burirum and Nonthaburi). Attempts are focus to demonstrate in province with potential earthquake area - Chiangrai province and a potential province for flood waste- Pitsanulok province. Two special sessions in international conference are plan in March (the 3INCs) and November (SEE Conference), respectively.

Conceptualizing, Implementing and Measuring the Circular Economy from the Micro to the Macro Level (Circularity^3)

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Project duration: 3 years, from 1 April 2023 to 30 March 2026
Current progress: 20 %

Abstract:
The research team has focused on studies in Work package 1 Conceptualization in the 1st 6 months. The work is jointly planned between researchers from Germany, Thailand, Japan, Turkey and Taiwan through progress meetings. In addition, the research team There was a small group meeting with the research team from AIST, Japan. To plan operations in designing methods of operation exchange of information and cooperation in analyzing results at the innovation level together, by dividing the operations into 4 case studies, with the research team from Thailand being responsible for 2 case studies within the entire project period of 3 years, focusing on business model studies and/or customer perception analysis of Circular Economy measures for electric vehicle and mobile phone batteries. To make comparisons in terms of research methods and study results with a case study conducted in Japan. In addition, Stakeholder participation has been given great importance in this project. The study will include data collection designs and periodic meetings to listen to opinions from various sectors, especially the Thai Energy Storage Technology Association (TESTA) and the Pollution Control Department, in order to improve the research methods and study results.

Rationales/Problem statements:
Under Net Zero Policy commitment, various sectors including the transportation sector have to reduce carbon dioxide emissions. One of the current driving measures is increasing the use of electric cars. As a result, there is a huge demand for lithium-ion batteries. On the other hand, the production process for such batteries requires (1) rare raw materials such as lithium, cobalt, and nickel, and (2) large amounts of energy. This leads to environmental and social impacts from the production process. Therefore, it is necessary to plan to develop a system for managing batteries after their lifespan to prevent environmental impacts that will occur if a system for proper management is not in place. Furthermore, the battery manufacturing industry in the future can be a source for producing renewable resources for use in battery production at a reasonable cost.
Circular Economy concept, for example, reproducing, reusing. and recycling has come to play a key role. Because it can reduce the risk of supply shortages and reduce environmental impacts. However, there are obstacles to Circular Economy measures for electric vehicle batteries. That is, the collection rate/quantity of battery waste is not very high. As a result, the economic cost-effectiveness of recycling plants is low. Therefore, every sector needs to create an enabling environment, such as policies, regulatory frameworks, business models, etc. The study investigates business environment framework and the linkages between factors, macro (national policy/regulatory framework) and sub-level factors (Market/Business Ecosystem) to support the recycling business of electric vehicle batteries.

Objectives:
1. Study the business model and roles of appropriate players in the electric vehicle battery recycling business in Thailand

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2. Propose business models and related policies to promote the electric vehicle battery recycling market

Progress/Findings/Results:

The research team focus on WP 1 Conceptualization. A detailed plan of the research framework was carried out. Research methods and expected results for operations in WP 2. Furthermore, the research team reviewed relevant literature and attended meetings with stakeholders in total of 5 companies, including automobile assembly companies, motorcycle battery inspection company, and the company conducts reuse/repurpose/recycling together with TESTA to understand the context of recycling business models in Thailand.

In the literature review section supply chain stakeholders and business model options are outlined. Stakeholders that should be considered in business design are: battery collector/separator industrial agency and recyclers. Recycling can be either centralized or decentralized. This will be designed and studied in the detail next.

Conclusion:

As for the first 6 months of operation, the research team has focused on studies in Work package 1 Conceptualization. The work is planned jointly between researchers from Germany, Thailand, Japan, Turkey and Taiwan. The Thai research team will be responsible for two case studies, focusing on business models and/or customer perception analysis of electric vehicle battery recycling and mobile phone to make comparisons in terms of research methods and study results. The study will include engaging inputs and opinions from stakeholders (Thai Energy Storage Technology Association (TESTA) and Pollution Control Department) periodically.

Current Output: conceptual framework and working in progress

Challenges/Problems and Possible solutions:

Meaningful stakeholders engagement and quality data collection are challenges that will be included in the experimental design and execution.

Future plan:

Actions during the first 6 months focused on joint discussions between network partners from all universities and research institutes to design goals, how to conduct collaborative research and detailed implementation guidelines to achieve the goals in each period throughout the 3-year project period, mainly using online meetings. There are regular and continuous meetings together and sharing ideas according to the conceptualization and work plan both online and site visit. The future work can be done efficiently.